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DRAM OXIDE SCREENING METHODS

McDonnell Douglas Missile Systems Company

Douglas R. Younkin

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13. ABSTRACT (Maximum 200 words)

The objective of this program was to evaluate "non-aging" screens that characterize maximum refresh times versus supply voltage in DRAMs. Extensive refresh characterizations were done, followed by accelerated life testing of DRAMs with periodic refresh characterization. The characterizations defined 1000 worst-case and 1000 random memory cells per part as the freak and main populations of refresh time and measured the sensitivity of their refresh times to voltage. Accelerated life testing at high voltage stress was performed in an attempt to generate oxide-related failures. Six parts from two vendors were tested for individual bit variable hold time (VHT).

Although we did not observe any TDDB failures during the life tests, our test results demonstrate that the 64K DRAM technology is highly reliable. Since only one recoverable failure (Vendor 2 S/N 338) occurred after 757,000 part hours (316,000 hours for vendor 1 and 441,000 hours for vendor 2), at near catastrophic voltages, we were unable to correlate initial bit refresh time with lifetime.

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DRAM OXIDE SCREENING METHODS

This project was undertaken to try to assess the need for and the effectiveness of additional DRAM screens which use refresh time measurements to identify individual bit storage cells with unusual leakage current characteristics.

When this project was started, there were ten year old references in the literature implying that high voltage reliability screening was being done by at least some US manufacturers of dynamic random access memories (DRAMs). Yet specific application details and their effect on yields and reliability were not fully described, perhaps because they were a part of wafer level testing generally considered to be proprietary trade secrets. As a result, these tests (and others which have followed) were not included in commercial device data sheets, were not fully understood or trusted, and certainly did not appear in military specifications for such devices. Perhaps a part of the reason was a phobia about tests which might apply voltages above maximum ratings.

It seemed clear that if there was significant benefit and little cost, such tests should be specifically described, standardized, and called out. But this was not occurring spontaneously in the industry. At the same time, the DRAM market became depressed for domestic suppliers. Even so, a decision was made to solicit proposals from suppliers and military users of DRAMs to clarify and demonstrate such tests. Unscreened devices were to be characterized and stress tested to determine whether abnormal refresh times indicated unreliability. Although no vendors submitted proposals, two donated parts. The parts exhibited interesting bit refresh time characteristics, but the stress that could be put on the devices in life test was limited by device voltage capability, and it was not possible to determine whether bits with low, high, or with unusual supply voltage dependence were prone to early catastrophic failure. In retrospect, a larger sample size or very much longer stress time may have helped. The extensive requirements in this project for physical analysis of failed bits was redirected to the analysis of bits with anomalous refresh times, but was unrevealing.

Perhaps a better approach to future work of this type might be a cooperative effort between a supplier and a customer in which the customer is allowed to characterize refresh times for a very large number of devices, and the supplier does normal burn-in, final testing, and failure diagnosis, telling the customer which devices and bits failed, and the customer does final refresh characterization if needed. An even better approach would be for all suppliers to do the experiment and share all the results with all customers.

Significant drifts were noted in the mean of random bit population refresh times in some of the test devices, however, these devices had not failed nominal specs at 4000 hours. Also, it was verified that variable hold time is a real phenomena in typical devices, although not much of a concern because refresh time specifications were very conservative for the devices tested. However, a very limited number of devices, and a very limited crossection of production lots were tested, and so not much can be said about the variance of VHT across production lots.

We have done additional VHT testing in-house at RADC. This work will be summarized in a technical report. Copies may be obta ined by contacting the undersigned or mailing the request form at the end of this report.

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Preface

The work described in this report was performed between September 1987 and April 1990 by the Product Integrity Technology group of the McDonnell Douglas Missile Systems Company (MDMSC). This work was performed for the USAF Rome Air Development Center under Contract Number F30602-87-C-0194. Daniel Burns of the RADC Reliability Physics Branch served as the Government Project Engineer, providing technical direction. In addition to the many McDonnell Douglas personnel who contributed to the program, special thanks are extended to Gerry Horst, Merrill Koenig, Roy Maurer, Ed Sisul, Gary Weaver, and finally to Alvin Sasaki for providing engineering management of the program.

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1.0 Introduction

High-voltage burn-in has traditionally been one way of accelerating defective memory failures. Unfortunately, as with any aging burn-in, a portion of the useful lifetime of all exposed parts is used.

On the other hand, non-aging screens identify some measurable parameter, (such as timing variations or leakage currents) that will indicate if a particular defect exists. Some maximum and minimum value for the parameter are specified that are probably within manufacturing or design limits, but measured values outside the range should indicate that the defect exists and would exhibit itself relatively early in the part lifetime. Since non-aging screens may be able to detect defective parts without subjecting them to aging stresses they are a desirable alternative to burn-in.

In Dynamic Random Access Memory (DRAM) memory cells, the refresh time is the amount of time that the cell capacitor can hold its data before the voltage level needs to be refreshed. The maximum refresh time may be a key in revealing variations in leakage from the cell. Defects in the memory capacitor dielectric are more likely than other leakage mechanisms to affect the leakage rate from the cell at room temperature, so lower refresh time measurements should indicate a high leakage rate from the cell due to dielectric defects. That lower refresh time is the type of defect symptom that is ideal for a non-aging screen. Because of this characteristic DRAMs provide an excellent vehicle for demonstrating the feasibility of non-aging screens.

Since DRAMs rely on the proper functioning of each memory cell capacitor, eliminating every defect is critical. Defects in the memory cell dielectric are a special concern because they are subtle, and conventional test methods cannot detect them.

High-voltage burn-in has been used with some success in removing parts with dielectric defects. However, by the time defective parts fail, the remaining good parts have also been aged significantly. As semiconductor part processing becomes more consistent, and gate dielectric thickness decrease, yield loss from this type of aging screen will become greater. Hence, there is a need to investigate a non-aging screen.

Additionally, a new phenomenon has been observed relating to unstable refresh times of DRAMs (Reference 1). Refresh times could potentially pass a screening test and at a later time "hop" to a lower value that may be insufficient to maintain stored data integrity. This phenomenon needs further study.

2.0 Program Description

The objective of this program was to evaluate "non-aging" screens that characterize maximum refresh times vs. supply voltage in DRAMs. The end result was to determine a standardized 100% oxide-defect screening test method and to determine the cost and benefit of using a screen test. To accomplish the objective, we conducted extensive refresh characterizations, followed by accelerated life testing of DRAMs with periodic refresh characterization during life test. The characterization defined the freak and main populations of refresh time and measure their sensitivities to voltage. Accelerated life testing with high voltage stress was performed to generate sufficient oxide-related failures in a reasonable time. If a correlation existed, time dependent dielectric breakdown failures would be correlated with initial electrical parametric measurements to develop a screen.

Our investigations for a non-aging DRAM oxide screen is based primarily on research by Meyer and Crook (Reference 2) which indicates that a defective oxide results in a large increase in leakage current. We used the individual memory cell maximum error-free refresh time as the measure of leakage current, since this value of refresh time is inversely proportional to leakage current. To achieve this we minimized thermally generated leakage currents (such as transfer gate subthreshold leakage and junction leakage) by making refresh time measurements at 70°C. Also, as noted in Reference 2, the defect leakage current must be measured before significant charge trapping in the defect has occurred. Measurements with these restrictions prevents the "walkout" effect from masking defect leakage current. The "walkout" effect occurs after the storage dielectric has undergone "aging", that is, kept in a charged state for a significant period of time. We avoided masking from walkout by measuring refresh time on test parts that have not been aged.

To determine the effectiveness of initial, individual cell refresh time measurements as an oxide defect screen, we aged a large number of DRAMs using a high voltage stress life test. We expected that the life test would provide failures of both defective and non-defective storage capacitor dielectrics and provide data for measuring the screen effectiveness.

A small sample size experiment was also performed to determine to what extent refresh time instabilities were present. These instabilities have been referred to in the literature as Variable Hold Time (VHT).

Our overall plan for conducting this program is shown in Figure 2-1. This figure shows the work flow and illustrates the interrelationship between program tasks. An overview of the specific testing to be performed is shown in Figure 2-2.

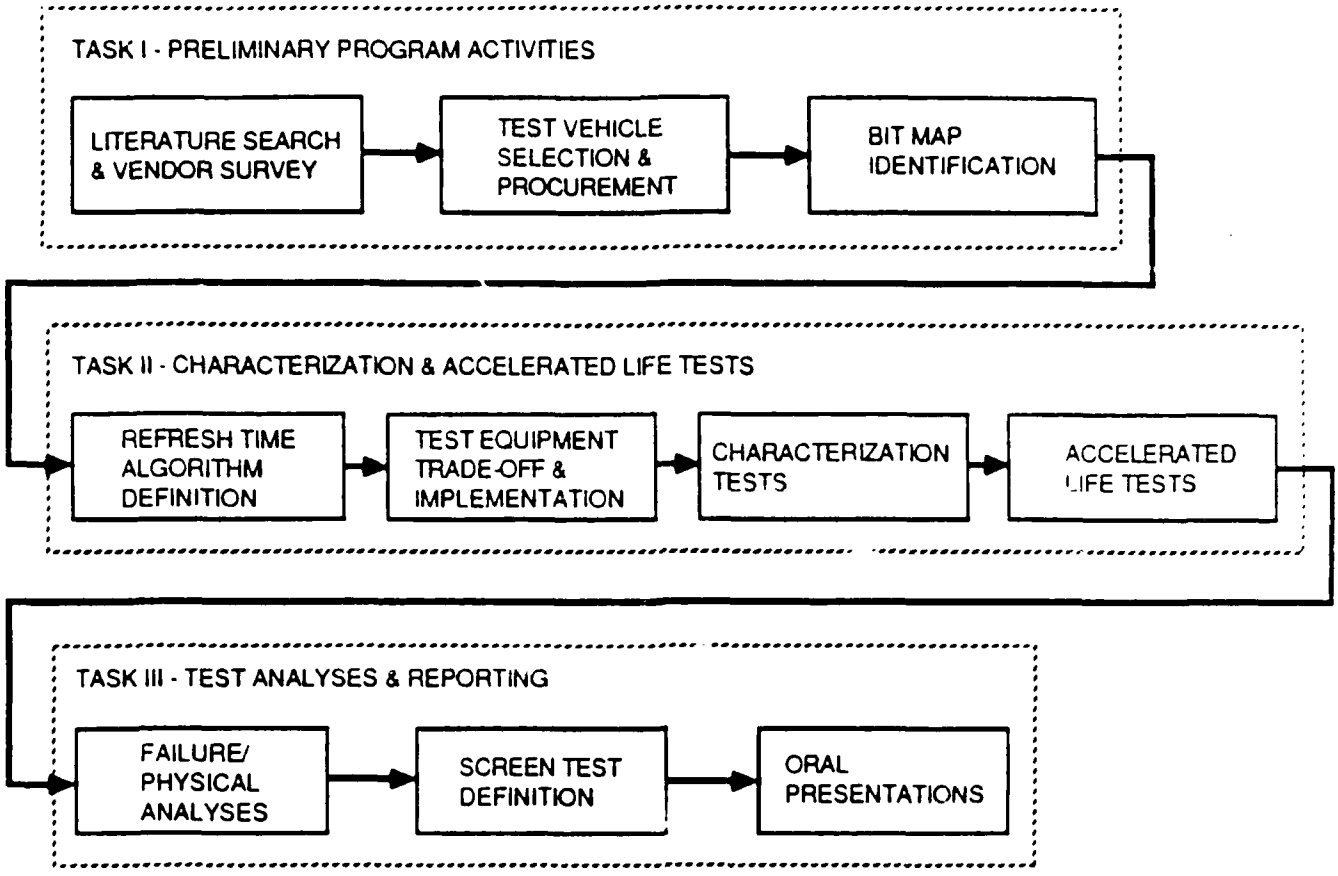
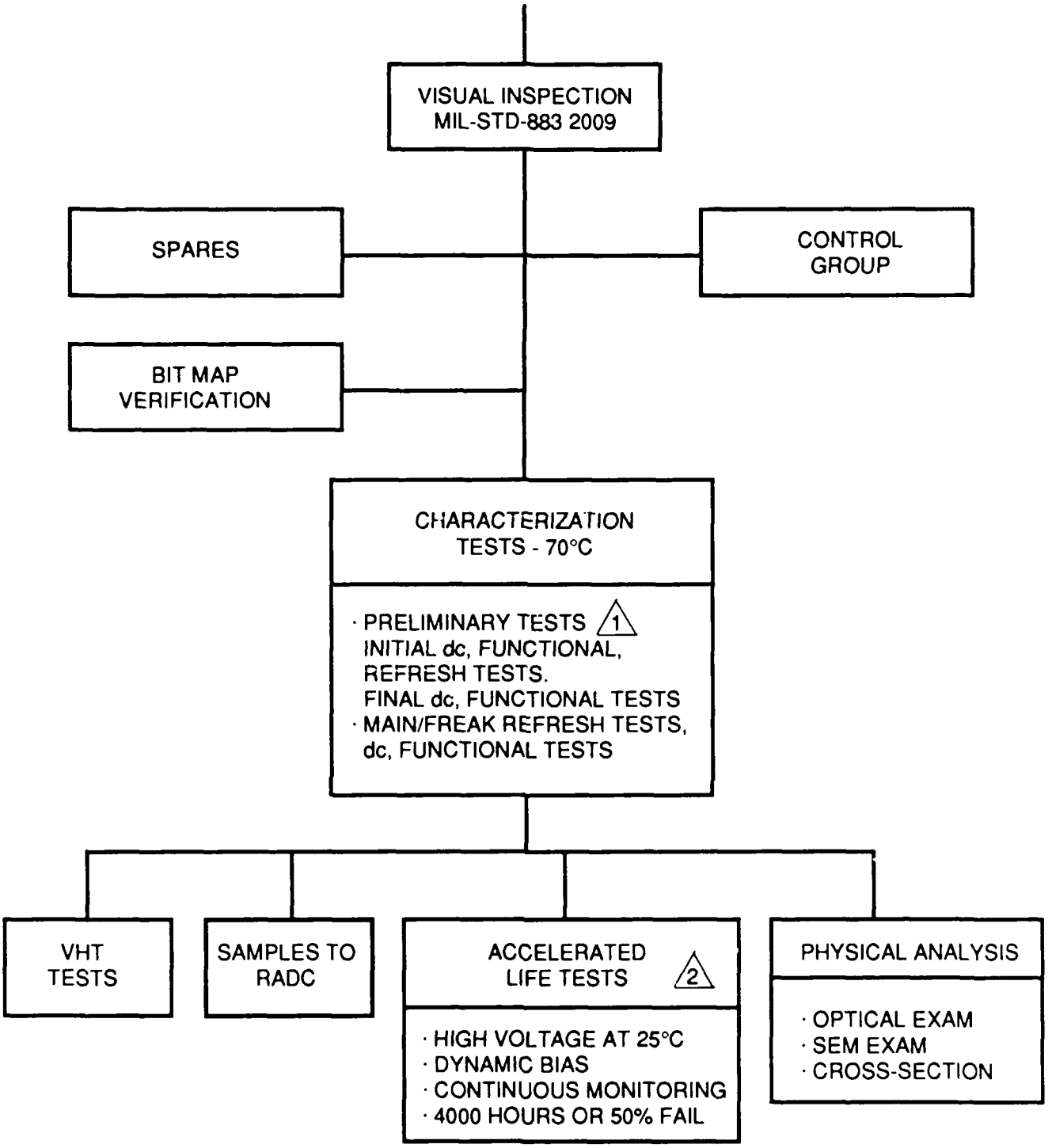


Figure 2-1. Program Work Flow



NOTES:

1. PERFORM PRELIMINARY TESTS WITH 10 DEVICES, REPEAT WITH 10 NEW DEVICES IF ANY DEVICE DAMAGED.
2. PERFORM PERIODIC dc, FUNCTIONAL & REFRESH TESTS AT 70°C.

Figure 2-2. Test Program Overview

3.0 Results Of Task I Preliminary Program Activities

3.1 Literature Search & Vendor Survey

Literature Search

We reviewed the current literature (1987) and assessed industry practices concerning oxide reliability screening of DRAMs, refresh tests, and time dependent dielectric breakdown. The search of the National Technical Information Service (NTIS) was accomplished using DIALOG database. Of the 207 items that matched the given descriptors, we identified 12 that were of interest to this program. Appendix A provides a bibliography of these references.

Vendor Survey

DRAM Manufacturers - To assess industry practices in screening, we obtained information directly from the vendors. We investigated screening methods and practices used at pre-burn-in electrical, burn-in, and post-burn-in electrical. The results of DRAM manufacturer's burn-in practices are summarized in Figure 3-1. Note that the burn-in test conditions differ for the different manufacturers. In addition, detailed information such as wafer probe and high voltage screens was only available from two vendors (Figure 3-1).

DRAM Users - We also conducted a survey to determine what screens are used by high reliability DRAM users. We surveyed McDonnell Douglas Corporation and our suppliers to determine what screens they are using for DRAMs in computers and storage assemblies applications. Figure 3-2 shows the results of our DRAM user survey. Note that the military systems manufacturers have limited applications for DRAMs, primarily because of the temperature limitation (110°C). None of the nine companies surveyed used refresh time as a screen.

Manufacturer	Pre-burn-in Electrical	Burn-in	Post-burn-in Electrical
Vendor A 1/			
Vendor B 2/	Patterns, dynamic tref (75 ms), static tref (8 ms), speed sort (83°C)	Four 4-hour sessions, each session with dynamic bias, at 125°C, at V_{DD}=7V, first session includes functional check, between sessions repeat pre-burn-in electrical with speed verify.	Repeat pre-burn-in electrical with speed verify.
Vendor C 2/		Dynamic bias at 125°C at V_{DD}=7.5V for 44 hours.	Functional tests at 25°C. Functional, parametric, and speed sort at 85°C.
Vendor D 3/		Dynamic bias at 125°C at V_{DD}=5.5V for 160 hours.	MIL-STD-883, Method 5005 Group A tests.
Vendor E 2/		Dynamic bias at 125°C at V_{DD}=8.0V for 10 hours.	Comprehensive functional and speed sort at 90°C.

Notes:
1/ No longer in DRAM business
2/ Commercial product
3/ Military product

Figure 3-1. DRAM Manufacturers Survey

Manufacturer	Initial Wafer Probe	Functional Tests	Wafer or Packaged Special High-voltage Screens
Vendor B	Functional patterns at VDD=4V, 6V (with substrate at -1V, -3V). At 65°C military, 50°C commercial. If fail, log how many failed bits.	Numerous different functional tests including VDD margin using static and dynamic refresh column patterns, dynamic refresh checkerboard, static & dynamic row refresh, walking diagonals, address parity patterns.	Cold stress: 7.0V, -25°C, static and dynamic refresh tests, most degradation with dynamic refresh (transfer gate degradation).
Vendor E	Cell characterization and refresh (disturb refresh at 5.5V & 7.0V, static refresh at 6.0V).	Ten different functional tests including X-Y margin, ADSEL, sliding diagonal.	Cold stress: 8.0V, -10°C, disturb refresh decreases with time.

Figure 3-1. DRAM Manufacturers Survey (continued)

User	Screening Method	tref Screen	Field Failure Rate	Remarks
User A	100% to MIL-M-38510/244 dc, pattern tests.	N/A	1 failed of 832 tested.	Limited usage CRT display.
User B	Buys to SMD. No special screen.	N/A	N/A	Program memory for test system.
User C	MIL-M-38510/244. No special screen.	N/A	100K usage.	Drafted /244.
User D	N/A	N/A	N/A	Uses SRAMs.
User E	Supplier screens.	N/A	N/A	Heads up display.
User F	N/A	N/A	N/A	Uses SRAMs.
User G	MIL-STD-883, Class B.	N/A	N/A	
User H	MIL-STD-883, Class B. Test at supplier.	N/A	N/A	Low volume applications.
User I	MIL-M-38510/244. No special screen.	N/A	256K usage.	

Figure 3-2. DRAM Users Survey

3.2 Test Vehicle Selection & Procurement

The primary considerations for the memory selection activity were (1) availability from multiple sources, (2) expected usage in high reliability applications, (3) status as a present or candidate MIL-M-38510 qualified part, and (4) one test vehicle with its storage gate connected to a ground potential, and the other test vehicle with its storage gate connected to a positive voltage. Obtaining parts that have not been subjected to any over-voltage or burn-in screen was also an prime consideration. Based on our survey, we selected Vendor 1 (memory plate connected to ground) and Vendor 2 (memory plate connected to V_{DD}). We obtained 144 DRAMs from Vendor 1 and 160 DRAMs from Vendor 2. The part allocation for the different tasks is shown in Figure 3-3.

	Vendor 1	Vendor 2
Controls	5	5
Characterization tests	10	10
To RADC	2	2
Physical analysis	2	2
High-voltage dynamic life tests	80	112
VHT tests	3	3
Total	102	134

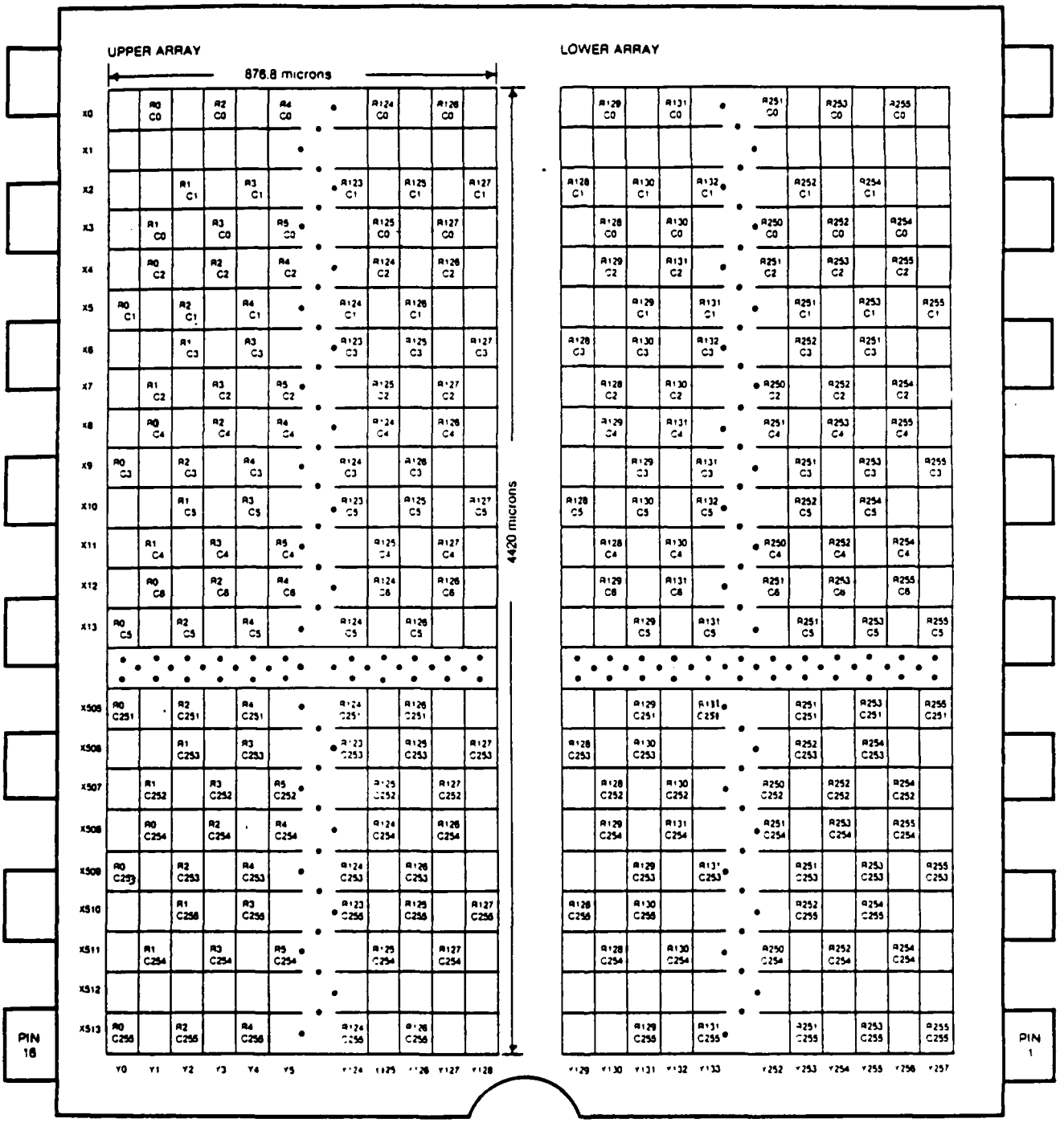
Figure 3-3. DRAM Part Allocation

3.3 Bit Map Identification

Refresh characterization tests must write external data so that each bit location has a high electric field on the gate dielectric. Therefore, it was imperative that we identified for each part type and manufacturer the physical bit map, storage cell gate connection, and charge storage conditions to store 0's and 1's.

We received topological bit maps from Vendor 1 and Vendor 2 for the selected part types, including whether data is stored as true or inverted and the voltage connection of the storage cell plate. Subsequently, we checked several random cell locations to ensure that we were correctly interpreting how data was stored. For each of these random cell locations, we wrote data to an address that should have charged that memory cell, then waited without refreshing that bit. After observing an expected decay of the data to the opposite state, we were convinced that we had correctly interpreted how the data was stored. Figures 3-4 and 3-5 show the address bits maps obtained from the manufacturers.

There are two critical reasons for identifying each bit's charge storage condition of 0's and 1's (what data written to a bit decays without refreshing (unstable) and what data does not decay without refreshing (stable). First, refresh time measurements initially require a charged memory capacitor. The refresh time is the maximum wait time for reading the memory capacitor as charged. Leakage through the capacitor dielectric plus leakage through other paths determines the maximum wait time. Second, accelerated life test stresses must be applied to all memory cell capacitors. Therefore, we must determine the proper algorithm such that during life testing we write data to each bit location so that all cells are stressed.



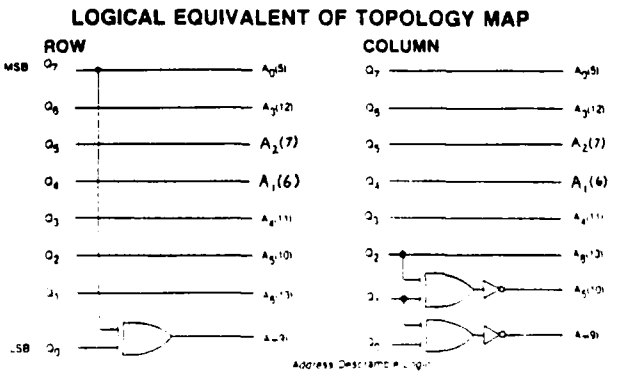
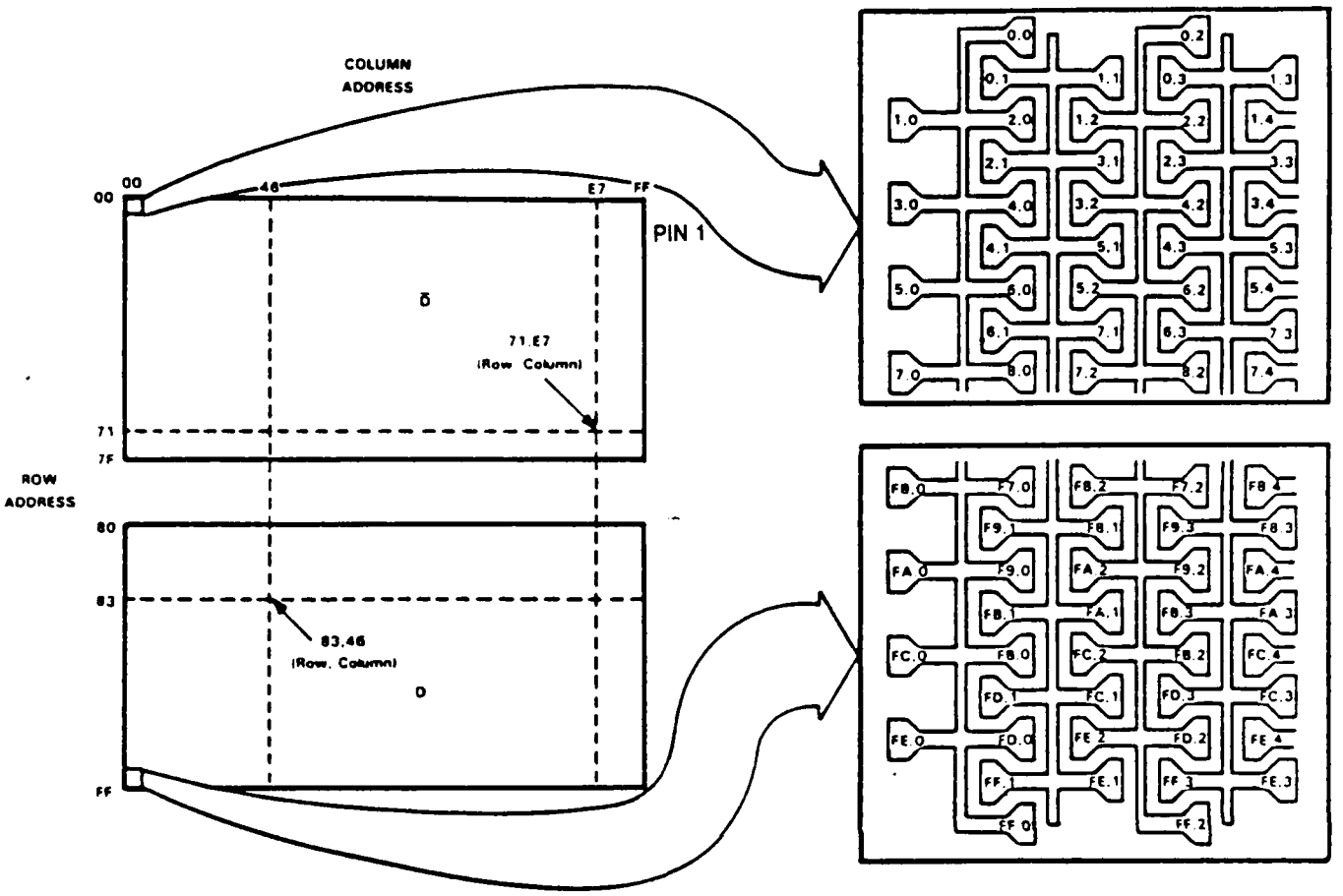


Figure 3-4. Vendor 1 Address Bit Map



DESIRED ROW OR COLUMN ADDRESS		WEIGHT	PIN NAME	PIN #
(MSB)	A7	2^7	A7	9
	A6	2^6	A0	5
	A5	2^5	A2	6
	A4	2^4	A1	7
	A3	2^3	A5	10
	A2	2^2	A4	11
	A1	2^1	A3	12
(LSB)	A0	2^0	A6	13

ADDRESS DESCRAMBLING

Figure 3-5. Vendor 2 Address Bit Map

4.0 Results Of Task II Characterization & Accelerated Life Tests

4.1 Refresh Time Algorithm Definition

The refresh time algorithm in DRAMs required careful consideration of the test method and part topology. After an evaluation of measurement times, we selected the dynamic disturb refresh over the static refresh. The dynamic disturb refresh provided the maximum stress to the tested memory cells and resulted in the shortest refresh test times.

The static refresh method writes data to the part and then disables the row select (RAS) and column select (CAS) lines for a specified period of time. The data is then read back from the part. This method provides the least internal circuitry parasitics but requires the longest test time. During evaluation tests using this method refresh times ranged from ten seconds to over two minutes.

The selected dynamic disturb refresh test, as outlined in Figure 4-0, writes data into the entire memory, and then continuously writes the inverse of that data into the even rows of the part for the specified refresh period, and then refreshes and reads the odd rows. The procedure is then repeated switching the odd and even rows. The disturb refresh method has the advantage of providing the maximum voltage stress between the test cell and cells in adjacent rows of the memory, and results in the shortest refresh times. Also, Vendor 1 and Vendor 2 disclosed that they measure refresh times in this manner.

Physical Topology

The physical layout and the method of storing data must be known to implement the disturb refresh test. For maximum disturb action, physically alternate rows must be continuously refreshed. Most 64K DRAMs do not implement the address addressing scheme in a topologically true manner. Thus, the bit map provided by the manufacturers was used to descramble the addresses. Because neither Vendor 1 nor Vendor 2 used redundant rows in their design, the implementation of the refresh test was not affected.

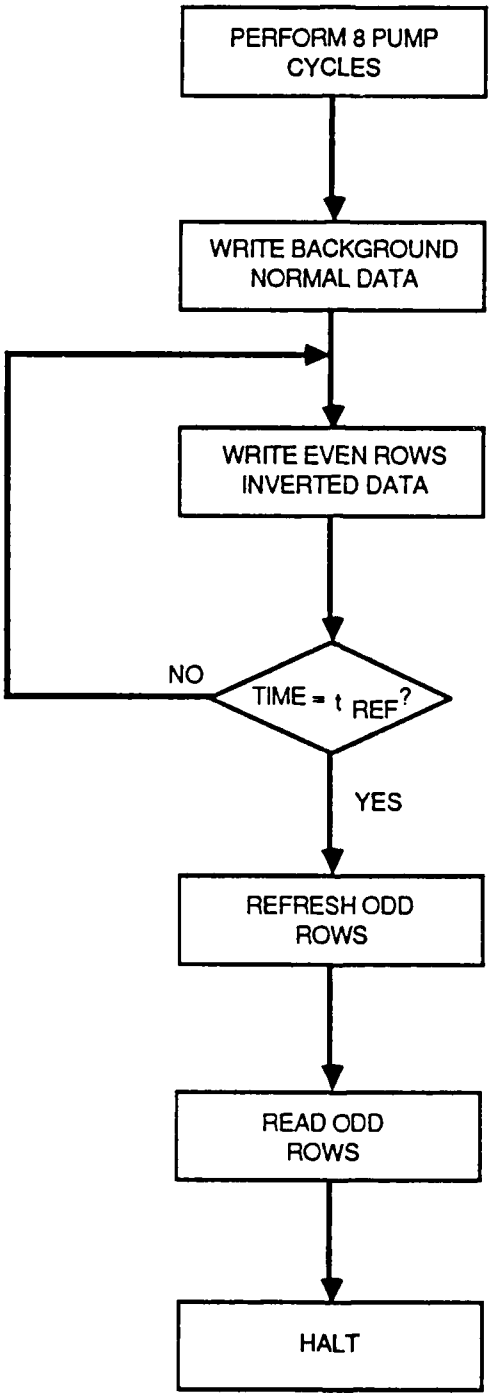


Figure 4-1. Dynamic Disturb Refresh Algorithm

Refresh Test Design
We used the disturb refresh algorithm that is shown in Figure 4-0. After performing eight pump cycles to assure proper part operation, normal data (defined to be that data which stores a charge in all cell locations) was written to all cells. Then, the even rows were disturbed by writing inverted data (data that depletes the charge in a cell location) into the even rows. This inverted data was continuously written to the even rows for the specified refresh period. Finally, the odd rows were refreshed and read. This algorithm provided maximum disturb action on half of the memory while measuring refresh time on the other half. To complete the test, the algorithm was repeated with the even and odd rows interchanged.

4.2 Test Equipment Trade-off & Implementation

Refresh Time Measurement System
Before deciding the most effective method of performing refresh measurements for the variable hold time (VHT) tests, we examined two options -- a personal computer (PC) implementation and an automated microcircuit test system.

Since long test times are characteristic of refresh time measurements, the capability of testing several parts in parallel was desirable. Most automated microcircuit testers test only one part at a time, and the PC implementation allowed parallel part testing. However, an advantage that the microcircuit tester has over the PC system was it is capable of testing not only at multiple temperatures, but at multiple voltages.

The deciding factor against investing development time for the automated microcircuit tester was that any innovative hardware or software solutions would not necessarily be transferrable to other types of dedicated test systems. Since most automated testers are relatively costly compared to PCs, and in our case, used for other semiconductor testing, the low cost personal computer implementation was a logical and cost-effective solution for the refresh time measurement.

We developed a portable system that may eventually be duplicated by others doing similar work, that was capable of testing at a single voltage, and at multiple temperatures, at a relatively low cost. Though the system was dedicated to testing refresh time, it could be returned to normal usage by removing the device-under-test (DUT) board and temperature plate.

In implementing the refresh time measurement system, several trade-offs were necessary. Since the test times were so long for either system, it was necessary to raise the test temperature to 70°C. Refresh time decreases at higher temperature, and typically an average refresh time of about 500 seconds at room temperature can be reduced to less than 15 seconds at 70°C. This temperature should still be at an acceptable level for dielectric defect leakage mechanisms to dominate. Elevated temperature and parallel testing allowed us to lower test times from 445 hours to 1.2 hours for six parts at a single voltage.

During each incremental refresh trial, the hardware DMA controller was disabled, halting the DRAM refresh controller. To keep the peripheral circuitry of the DUTs (and the rest of RAM memory!) refreshed during each trial, we read from address 0 (row 0, column 0) every 4 ms (refreshing row 0 and row 128 only), and in doing that we could not measure refresh times on those rows. However, this procedure

excludes less than one per cent of the refresh data for the entire part. It was decided that this was an acceptable alternative. The sequence of events at each cycle was as follows:

1. Mask row address strobe (RAS) to the DUT segment.
2. Disable DMA controller (including system refresh requests).
3. Allow RAS to DUT segment.
4. Read address 0 (rows 0 and 128) every 4 ms until time trial period has elapsed.
5. Mask RAS to the DUT segment.
6. Enable DMA controller (including system refresh requests).
7. Allow RAS to DUT segment.

Refresh times for each bit were measured by performing 100 test trials. At each trial, normal refreshes were withheld for a selected pause time. After the specified pause time, each bit was checked to verify the integrity of stored data. If a bit failed, the trial number was stored in a memory buffer location corresponding to the address of the bit. After the failure data had been saved, another trial was executed after incrementing the pause time. The sequence was repeated until the maximum pause time was reached.

To speed up testing while still storing as much data as possible, disk access was limited, and data was stored to disk only after all refresh testing was completed.

The personal computer system developed for refresh time measurement is shown in Figure 4-1. It was controlled and monitored by an IBM[1] PC/XT compatible machine, and allows simultaneous measurement of refresh times on six parts. The parts can be operated at temperatures up to 70°C through the use of a temperature controller connected to a plate that fits over the parts.

Normally, the system hardware refreshed two rows in the memory every 15 microseconds. We were able to turn off the system refresh to the DUTs, and control DUT refreshing by using the PC parallel port as a refresh strobe.

The original software was developed at Rome Air Development Center and tested a single part. The test software allowed the selection of: shortest pause time, longest pause time, and the number of discrete pause times or bins. We modified the software to test six parts simultaneously. Appendix B contains a listing of the test software for the refresh time measurement system and Appendix C presents the design of the six-position fixture that was used to mask RAS to the DUT segment.

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[1] IBM is a registered trademark of the International Business Machines Corporation

Figure 4-1. Refresh Time Measurement System

High-Voltage Stress Test System

We have performed high temperature and voltage screens on several different types of parts, using a custom designed life test system. The primary factors in attempting to find a PC solution to the high voltage stress test in this case were the ease of duplication, and the portable hardware and software solutions.

We modified commercially available memory boards to vary the V_{DD} voltage to the memories, rather than having to design, build, and debug complicated driver boards for the custom-designed system. The added feature of temperature variation available on the custom designed life test system was not needed for this application because stress testing would be conducted at room ambient temperature.

The ability to store all part failure data in files that can easily be transferred to other computers allowed us to more closely monitor the DUTs, and more easily analyze failure data. We have the capability to analyze trends in failed addresses, such as row or column failures. Previously, we had a hard-copy printout of the addresses, that had to be reentered in a new computer if further analysis was

required.

For this application the time required to modify the commercial memory boards made the PC solution less expensive and more logical alternative to a custom-designed life test system.

The high-voltage life test system (Figure 4-2) was controlled and monitored by an IBM PC/AT compatible machine. The 80286 microprocessor used in this computer allows up to 16 megabytes of physically addressable memory. We used this capability to access one and a half megabytes of memory for this project.

We modified commercial memory boards to vary the V_{DD} levels to the test parts and interface circuitry independently of the PC power levels. The high voltage levels on the V_{DD} pins of the memories were isolated from both the interface circuitry and computer power supplies. The V_{DD} levels of the interface parts were set slightly higher than the computer power level, so that the interface parts act as level shifters, with output levels to the computer at safe values, while the outputs to the test parts were elevated enough to allow more accurate access.

The primary concern was maintaining a high-voltage stress on each memory cell while monitoring functionality. Determining what data to write to produce a charged condition at each cell required using software to decode the part manufacturers logical-to-physical address and the board address. The addressing scheme of the memory boards remapped the PC addressing, so reverse-engineering of the memory boards was required. The high voltage stress for each cell was maintained by writing data that corresponded to the charged condition of the cell capacitor. This charged state was restored to cells after each functional check.

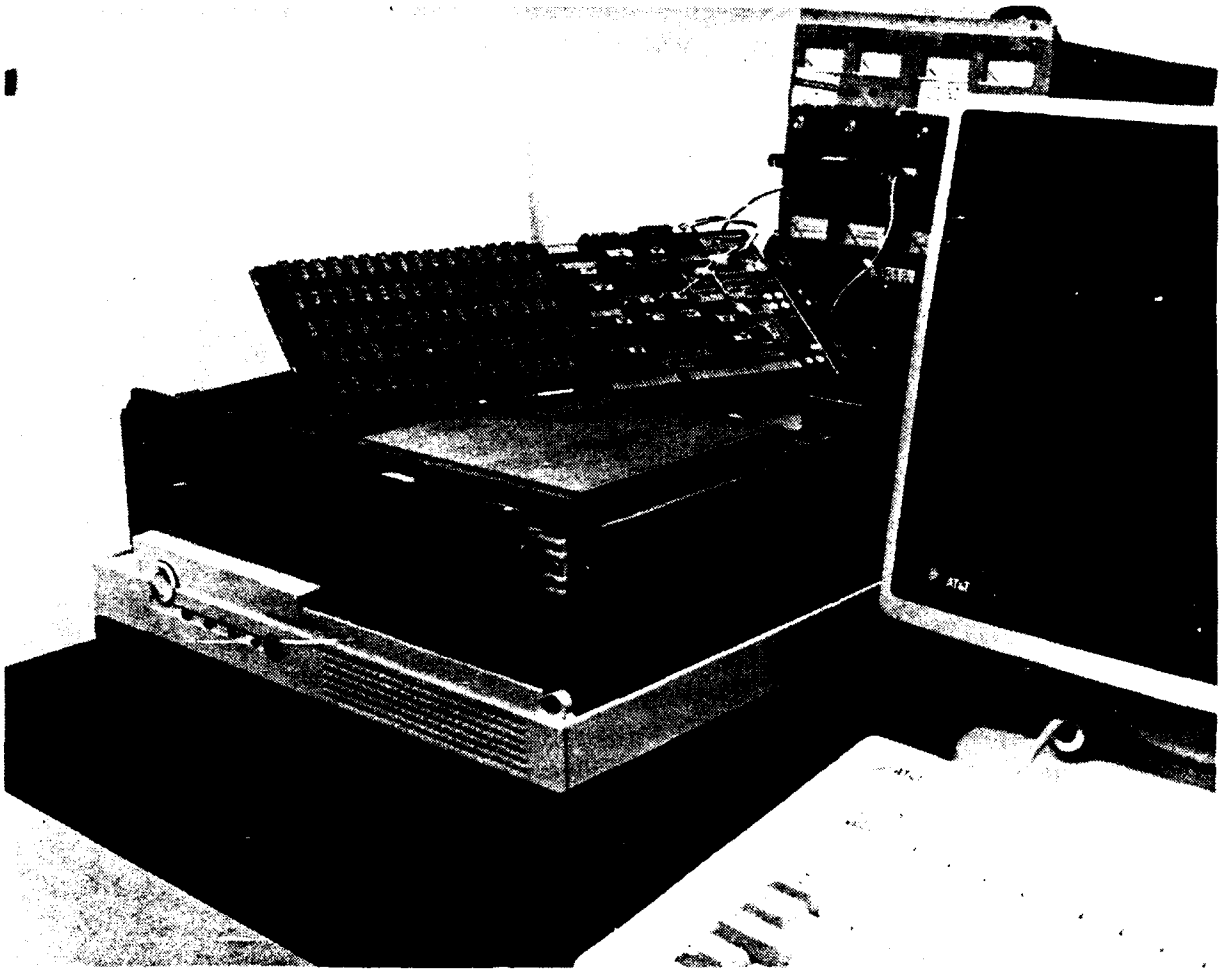

Figure 4-2. High-Voltage Stress Test System

Cell addresses, failure times, and failure modes were necessary to provide all of the data necessary for analysis. Since we needed to know exactly how long a part had been under stress when cell failures occurred, we tracked the following information: (1) when a board was placed in test, and (2) the amount of time the board was out of test, so that failure times, in hours-under-stress, can be calculated. Masks, with bits corresponding to each cell, were used to prevent redundant failure logging, or long searches through data files for previous conditions. The corresponding mask bit was set when a cell failed, and no further failure data was stored for that cell. Since we needed to monitor intermittent failures, we used the masks to determine when cells that previously failed started to pass. When this occurred, the mask bit was reset so that further failures can be logged.

We had the capability to limit the amount of data generated. The entire part could be masked when removed from test so that no further data for the part was logged. We also compressed all of the data for each cell failure into a four byte record that contains: (1) the sixteen bit cell address within the part, (2) the failure time (in hours since the beginning of stress), and (3) whether it failed storing a one or a zero. Because each DUT has a separate data file, serial numbers or part numbers do not need to be stored.

Normally, memory failure or empty sockets in a row of memories being accessed caused parity errors and system lockup. Parity errors from the test boards were inhibited to allow us to continue testing when cells failed, or even when failing parts were removed from test.

4.3 Characterization Tests

The purpose of the characterization tests was to (1) determine if the refresh characterization tests provided repeatable and consistent results for a sample of each manufacturer's parts, and (2) to assure that the refresh tests do not damage the DUT. This knowledge was then used to adjust the refresh test as necessary such that the test can be safely applied to the life test parts. Our characterization test flow (Figure 4-3) met the program requirements to determine the optimum refresh test for this program.

The first step in the characterization test flow was to perform parametric and functional tests on a sample of ten parts from each manufacturer.

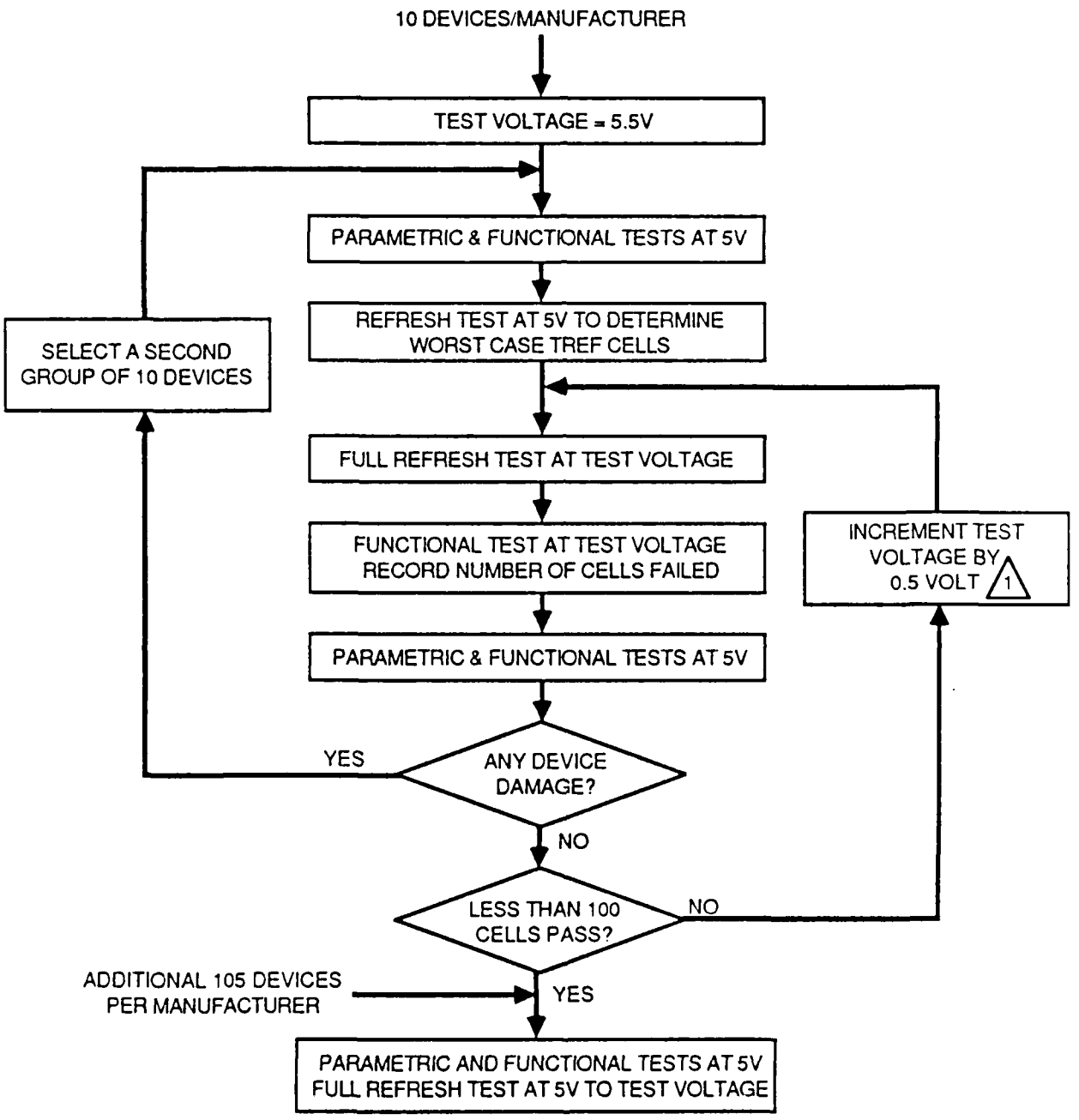

Figure 4-3. Characterization Test Flow

The next step was to define the freak and main cells for each part. The main population was selected by randomly generating 1000 addresses. These 1000 addresses were used for all parts. The freak population, or 1000 worst case refresh time cells, were generated for each part by performing the previously designed refresh characterization test at 5.5 volts and using a binary search technique on the refresh delay, until each memory had only 1000 cells failing. These 1000 addresses were recorded for each part for use in subsequent refresh testing at 0, 160, and 4000 hours of life test. Although selecting worst case refresh time cells at 0 hours does not guarantee that these will also be worst case at later measurement times, it was more important to be able to record the performance of individual cells over time. Also, the minimum and maximum refresh times were determined for each part using the refresh characterization test at 5.5 volts and recording (using a binary search technique), the refresh time delays where all the cells fail and all the cells pass. The minimum and maximum refresh times were adjusted as required to provide boundaries for the refresh test to guarantee that valid data would be obtained on all parts during all refresh tests.

The full refresh characterization tests were performed at a test voltage starting at 5.5 volts, recording the refresh times of each cell in the freak and the main populations. This was followed by a functional test at the test voltage with the total number of failed cells recorded. The 5 volt parametric and functional tests were then performed again to check that none of the parts have been subjected to any damaging conditions.

If the parts were not damaged at the test voltage, then a check was made to see if less than 100 cells passed the functional test. If more than 100 cells passed, the test voltage was incremented by a 0.5 volt step and the sequence of full refresh characterization test, functional test, and parametric and functional test was repeated. This procedure continued up to the maximum safe voltage. The maximum safe voltage used for the characterization tests was the maximum non-catastrophic supply voltage as determined by independent bench tests (see Section 4.5).

Once this section of the test sequence was performed on each manufacturer's ten parts, the data was reviewed to assure that the data was consistent for both manufacturer's parts. The aim of increasing the supply voltage was to provide the maximum voltage in the memory cell while not inducing any damage to the parts.

Finally, each manufacturer's parts were subjected to the parametric and functional tests at 5 volts and the full refresh characterization tests at supply voltages from 5.5 volts to the maximum safe voltage in 0.5 volt steps. Individual cell refresh times were recorded for both the freak and main populations at all supply voltage levels. Also at the same time, a data summary for each part was output to disk, including the number of bits failing in a particular refresh time trial at each supply voltage level. We performed these tests using an incremental-step refresh test, and using a binning method to store the refresh times for each of the freak and main cells that fail at each step. We performed this testing using an automated part handler and tested the parts overnight with a minimum of operator intervention.

We measured refresh times at 55°C and 70°C and found that the data for both part types were similar, so we performed all subsequent refresh tests at 70°C to reduce test times. Also, the data observed at the test voltages during

characterization testing did not provide much additional information over measuring refresh times at three voltages. Therefore to further reduce test times, we measured initial and interim refresh times during life test at only three voltages (5.5, 6.0, and 7.0 for Vendor 1 and 5.5, 7.0, and 8.0 for Vendor 2). With these optimizations, the time required to measure refresh times of the 2000 cells at the three selected voltages at 70°C were 3.4 hours for Vendor 1 and 1.5 hours for Vendor 2 for each part.

4.4 Variable Hold Time (VHT) Refresh Monitoring

We measured in parallel the refresh time of all bits (except those in rows 0 and 128) in each of three parts from each manufacturer. These measurements were repeated 60 times at 70°C ambient temperature. The refresh times were measured using a binning method with the interval between 1 millisecond and 60 seconds divided into 100 bins. The collected data consisted of 22.5 megabytes of data files.

To summarize this data, we looked for refresh time hops by using analysis software provided by RADC. Hops were categorized by magnitude and number of hops. Appendix D contains the summarized hop information. The data was sent to RADC for further analysis.

4.5 Accelerated Life Tests

To select the elevated voltage for use during the life tests, we conducted a two-step verification procedure. The first step was to conduct a step-stress test to select the elevated voltage condition. For the second step, we conducted a "mini" life test using a sample of parts to verify that the long term exposure to the selected voltages would not be catastrophic.

Step-stress test
The goal of step-stress testing was to define stresses to be used during life tests that would induce 50% of the parts per manufacturer to fail before 4000 hours. Since acceleration of failure depends exponentially on voltage, voltage selection must be conservative to avoid shortening the lifetimes too much or atypical catastrophic failure.

We subjected two parts per manufacturer to an incremented voltage-step test beginning at 6.0 V and increasing in 0.5 V increments. We maintained the parts at each selected voltage for 15 minutes. Data was written to the DUTs so that all bit locations were in the charged state. Following each stress step, each part was tested at 5.5 V to verify that all bits were still functional.

For both manufacturer's parts, all parts remained functional after each step until a catastrophic voltage level was reached. (Catastrophic is defined here as failure of much of the memory cells and excessive I_{DD} supply current.) The catastrophic V_{DD} level was found to be 9.5 V for Vendor 1 and 10.0 V for Vendor 2.

To avoid these catastrophic levels during life testing, we reduced the applied voltages by 0.5 V: 9.0 V for Vendor 1 and 9.5 V for Vendor 2. To verify the suitability of these voltages for life testing, we conducted a "mini" life test.

"Mini" life test
A "mini" life test consisting of five parts per manufacturer was conducted to verify

that the selected life test conditions were suitable for long-term stress applications. Although the selected V_{DD} voltages were below catastrophic levels, we need additional assurance that all parts would not fail, before 100 hours for example.

We operated the "mini" life test for 1000 hours and did not observe any failures or degradation of dc, ac, or functional parameters. This result confirmed that the selected voltage levels were "safe."

An additional constraint on stress selection was that the DUTs must initially operate error-free to assure that every bit is under constant stress (all bits remain in the charged condition) and to allow continuous monitoring of the DUTs for failure. However, we noted during the "mini" life test that many DUTs did not operate error-free while at the accelerated voltages. There were not only hard failed bits detected but also many of the bits exhibited fail-to-pass transitions. Since the primary goal of the life tests was to accelerate failures, we could not reduce the applied voltages to allow error-free operation.

Life test

Accelerated life testing must generate sufficient oxide-related failures in a reasonable time period to provide the data needed for screening oxide defects. Therefore, we subjected 80 parts from Vendor 1 and 112 parts from Vendor 2 to life test stress conditions (room temperature, high V_{DD} voltage with dynamic bias) for 4000 hours. The following paragraphs provide details of our approach to stress selection, life test implementation, and periodic testing.

Implementation - We conducted the life tests for the selected parts using the IBM AT compatible hardware described in Section 4.2 (Test Equipment Trade-off and Implementation). All DUTs were dynamically operated while biased at the selected V_{DD} voltage such that data written to the parts would put all bit locations in the charged state. Parts did not operate error-free at the selected voltage stress; however, a dielectric breakdown failure would be detected as a hard error. Time of hard error detection and address of the failed bit was logged for later analysis.

Since voltage exponentially affects median failure time (Reference 3), we regulated the V_{DD} voltages to the DUTs. We used regulated voltage supplies for each group of 80 DUTs and incorporated current limit provisions on the voltage supplies to protect the DUTs against excessive current. If one part had failed catastrophically so as to draw excessive current, we would have been able to note the problem with continuous monitoring and remove that part.

Periodic Testing - We performed initial and interim dc, ac, and functional tests on our Tektronix S-3270 AMTE at 70°C and normal operating voltages at the following times: 4, 8, 16, 32, 64, 160, 240, 500, 1000, 2000, and 4000 hours. We also performed refresh time tests at 70°C with our S-3270 at 0, 160, and 4000 hours.

To assure our automated tester's stability, we performed control sample measurements. Before testing the DUTs during periodic testing, five unstressed control parts for each part type were tested.

The results of interim dc, ac, and functional testing during life test are shown in Figure 4-4.

Test Cell	Vendor	Temp (°C)	V_{DD} (Volts)	Qty	Cumulative Failures At Hours Of Test										
					4	8	16	32	64	160	240	500	1000	2000	4000
1	1	25	9.0	80	0	0	1 2/	1	1	1	1	1	1	1	1
2	2	25	9.5	80	0	0	0	0	0	1 3/	1	1	1	1	1
3	2	25	9.5	32	0	0	0	0	0	0	0	0	1 4/	1 5/	1

Notes: 1/ Parts in test cells subjected to refresh tests at 0, 160, and 4000 hours.
2/ Part failed due to open output: failure occurred during ate testing.
3/ Part failed due to mechanical damage induced by parts handler.
4/ Part failed refresh parameter in dc tests.
5/ Part failed refresh parameter in dc tests, removed from life testing.

Figure 4-4. Life Test Summary-dc & Functional Tests 1/

5.0 Results Of Task III Test Analyses & Reporting

5.1 Failure Analysis

Single bit failures that occur as a result of TDDB should manifest themselves as a conductive filament (polysilicon) shorting the plate to the memory cell active region. This failure mechanism is irreversible and should not recover. Possible recoverable failure mechanisms include a shift in the threshold of the transfer gate transistor such that it does not shut off completely. This higher "off" leakage would cause a shorter measured refresh time.

One part in each of the test cells failed during life tests. The two failures in test cells 1 and 2 were not related to the life test stresses. However, the failure in test cell 3 (S/N 338) appears to be a valid failure. It failed the worst-case refresh parameter that was measured during the dc and ac electrical tests. This part failed a single bit and was verified at the 1000-hour test point using a PC-based test program that was used to pre-charge all memory cells before life test stresses were applied. The physical location of the failed bit was at row 140, column 224 and failure occurred when attempting to write a "0" (charged condition). Unfortunately, this bit was not one of the 2000 bits being monitored for refresh time during Tektronix S-3270 testing. Before further characterization could be performed, the failure recovered. This part was selected as one of the physical analysis parts to further investigate the failed bit.

5.2 Physical Analysis

Two parts from each manufacturer have been physically analyzed to determine the physical reasons for low or high refresh times. We looked for defects that could have contributed to dielectric breakdown. The die of one part from each manufacturer was delayered and 10 bit locations (five with the lowest refresh times and five with the highest refresh times) were examined optically for defects at each step at magnifications of 500X to 1000X. The examination was repeated using our JEOL 840 SEM at 500X magnification or higher. Typical views of each layer were photographed and are documented in Appendix E. Any defect or anomaly noted at the locations was characterized and photographed.

One bit location in an additional part per manufacturer was metallurgically cross-sectioned perpendicular to the storage gate dielectric. We used a precision, non-encapsulated sectioning technique and examined each of these parts in the SEM for defects or flaws in the polysilicon gate material, dielectric, or the substrate. The cross-sectioned photos are shown in Figures 5-1 and 5-3. Figure 5-3 shows some anomalies observed in the polysilicon of the transfer gate. However, since these anomalous "bumps" are on the top of the polysilicon, they should not affect the transistor operating characteristics.

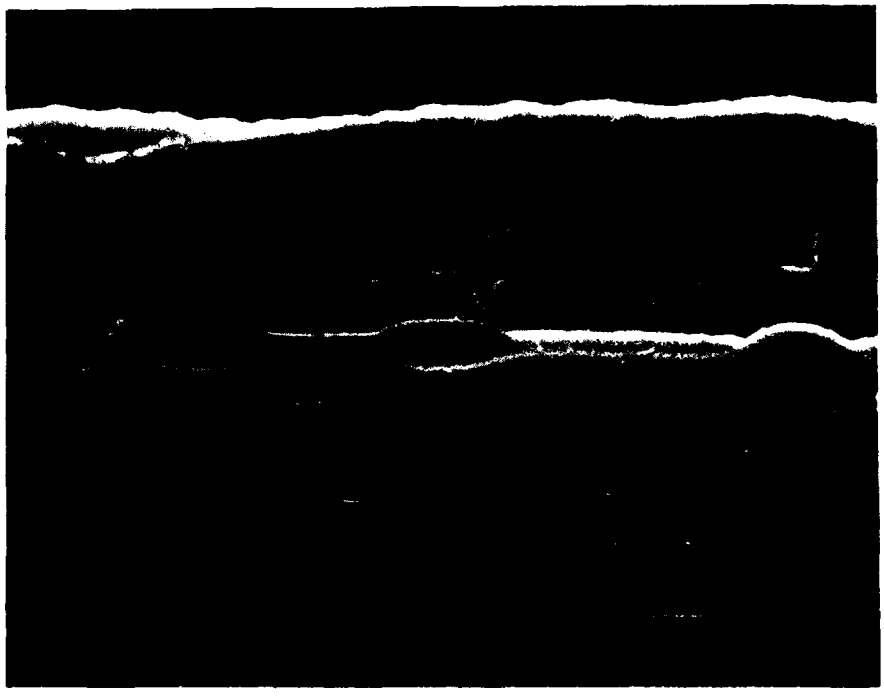

Figure 5-1. Cross-section of Vendor 1 Memory Cell

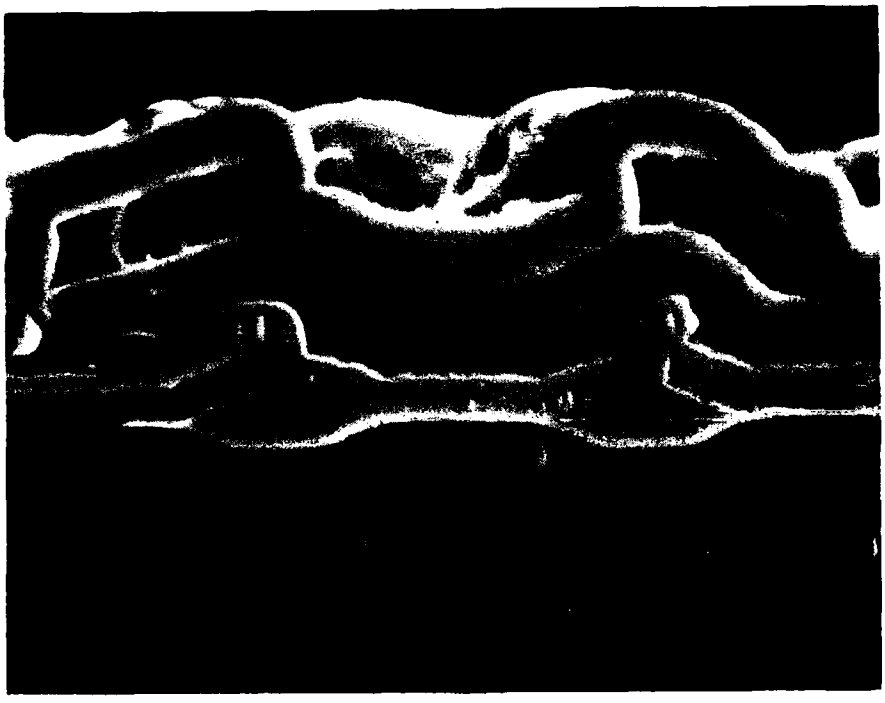

Figure 5-2. Cross-section of Vendor 2 Memory Cell

Figure 5-3. Anomaly in Vendor 2 Polysilicon

5.3 Screen Test Definition

If high voltage refresh time had correlated with early failure, then we were to define a reliability screening method to detect leaky oxides. However, no TDDB bit failures were found and the single bit failure that was observed had not been initially characterized for refresh time. Because of this lack of failure data, a screen test can not be determined.

Our survey of DRAM manufacturers shows that refresh time is used as part of defect screening. This practice is not standardized across manufacturers and seems to be more of an empirical than a well-understood methodology. Screening out parts with low refresh time bits "seems" to make sense, but there is a lack of data to prove that these bits have a shorter lifetime.

If worst-case refresh tests are incorporated during wafer probe or burn-in electrical tests, there is minimal increased testing cost - no more than tens of milliseconds. A worst-case refresh test would be sufficient to detect and screen out low refresh bits, but are these bits a reliability problem? This question remains unanswered.

6.0 Data Analysis

6.1 Tektronix S-3270 Measurements

DC, AC, and Functional Tests

The results of dc, ac, and functional tests conducted during the life test were presented in Figure 4-4 on page 24. The dc, ac, and functional data measured at periodic intervals during life tests was stable and no drift trends were observed. The single valid life test failure (Vendor 2 S/N 338) occurred suddenly with no previous indication of degradation. It occurred after 757,000 part hours (316,000 hours for Vendor 1 and 441,000 hours for Vendor 2) at near catastrophic voltages.

To estimate part failure rates at use conditions due to memory cell dielectric failure, the appropriate acceleration factors must be calculated. The following equations were supplied by the vendors. For Vendor 1 at 9.0 V and a dielectric thickness of 177Å, the acceleration factor is:

$$\text{Acceleration factor} = e^{[(2.4\ \text{cm/MV})(9.0\ \text{V} - 5.5\ \text{V})/177\text{Å}]} = 115$$

For Vendor 2 at 9.5 V and a dielectric thickness of 200Å, the acceleration factor is:

$$\text{Acceleration factor} = 10^{[(3\ \text{cm/MV})(9.5\ \text{V} - 5.5\ \text{V})/200\text{Å}]} = 10^6$$

Refresh Times

The refresh times measured at 0, 160, and 4000 hours during life testing consist of seven megabytes of data which presents a formidable task of data analysis. To look for trends in this data, we calculated the mean and standard deviation (assuming a normal distribution of refresh times) for each serial number at each test voltage. The data for the 1000 random and 1000 worst case cells were treated separately. These results are presented in Appendix F. There were no consistent trends of mean and sigma as aging progressed during life testing.

We also examined scatter plots of memory cell refresh times. By looking at cells measured at two different voltages, a dependence of refresh time on voltage was evident as well as a significant amount of refresh instability. Sample scatter plots are also presented in Appendix F. The bits with lowest refresh time had no voltage dependence and were quite stable. For these bits, the dominant leakage path is possibly a high resistance filament in the dielectric or a sub-threshold leakage through the transfer gate transistor. Refresh instability observed in the other bits appears to be the intrinsic (non-defective) behavior of the memory cells.

6.2 Life Test Monitoring

The continuous monitoring software, operating throughout life testing, detected the single life test failure (Vendor 2 S/N 338) at 932 hours. We were therefore able to confirm the failed bit and establish the time of failure because of the data collected during continuous monitoring.

7.0 Conclusions and Recommendations

Although we did not observe any TDDB failures during the life tests, our test results demonstrate that the 64K DRAM technology is highly reliable. The single recoverable failure (Vendor 2 S/N 338) occurred after 757,000 part hours (316,000 hours for Vendor 1 and 441,000 hours for Vendor 2) at near catastrophic voltages. Using an acceleration factor of 115 for Vendor 1 and 10^6 for Vendor 2 to extrapolate failure rate to use conditions (V_{DD} = 5.5 volts), part failure rates are less than one failure in 3.6×10^7 hours for Vendor 1 and one failure in 4.4×10^{11} hours for Vendor 2. Since no TDDB failures were generated from the life tests, we were unable to correlate initial bit refresh time with lifetime. Therefore a 100% non-aging screen test could not be defined. Perhaps additional stressing of these parts would generate TDDB failures to give the opportunity to compare refresh time with failure time.

General trends of bit refresh times indicate that the low refresh bits (extreme outliers) are most stable with respect to refresh time. Given this observation, it appears that VHT presents a different phenomenon since VHT defines unstable refresh time.

Trade-off studies for hardware implementation of the VHT and life tests show that personal computers offer a good alternative to expensive test systems. Because the techniques developed are portable and because of their relatively low cost, personal computers provide a desirable solution to DRAM test challenges.

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Appendix A

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Appendix B

Source Code For PC-based Monitoring Of Refresh Times

Pages B3 through B16 Intentionally Deleted.

Please refer questions regarding this code to:

Dan Burns
RADC/RBRP
Bldg 3, Rm 1080
Griffiss AFB, NY 13441-5700
(315)330-2868

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Signature of Air Force
Approving Authority

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Name/Title of Air Force
Approving Authority

_____
Organization/Location

Appendix C

Six-position Fixture For PC-based Refresh Monitoring

Figure C-1 shows a diagram of our VHT monitoring fixture. Although there are eight positions in the fixture, memory constraints of DOS and the buffers for storing refresh information only allow six parts to be simultaneously tested for refresh time. Each DUT tested required 64K bytes of buffer space, the DUTs physically reside in 64K bytes, the test program required 64K bytes, and DOS used two segments (128K bytes).

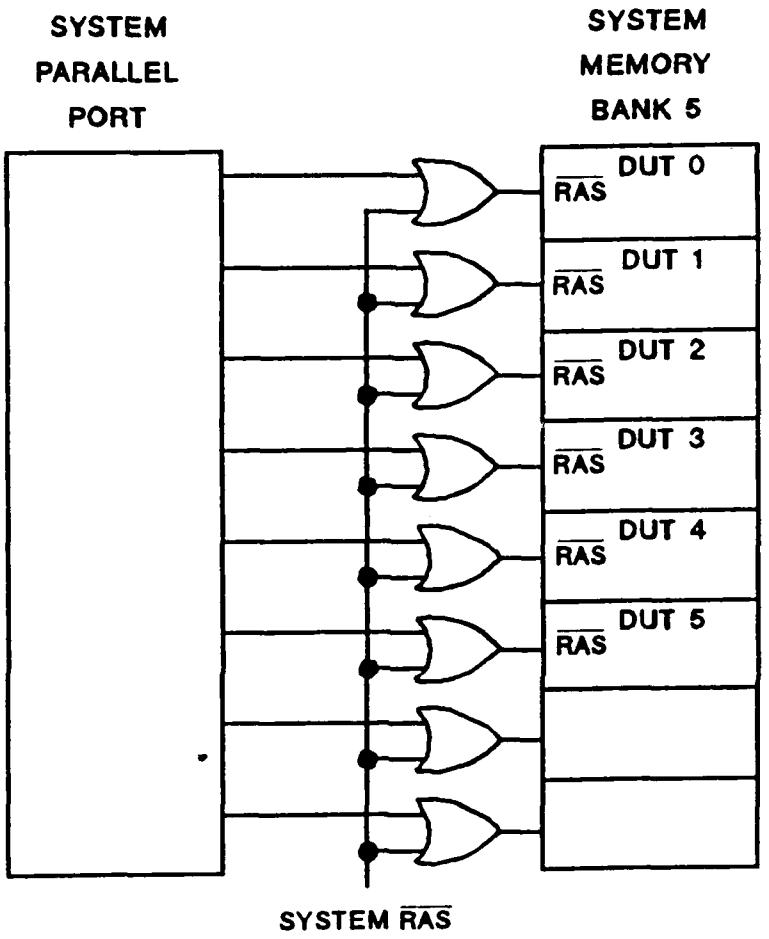

Figure C-1. VHT Monitoring Setup Accomodates Six DUTs Simultaneously

Appendix D

Test Results Of PC-based Monitoring Of Refresh Times

Table of Contents

Paragraph	Page
Vendor 1 S/N 124	D3
Vendor 1 S/N 125	D7
Vendor 1 S/N 126	D11
Vendor 2 S/N 326	D15
Vendor 2 S/N 327	D19
Vendor 2 S/N 328	D23

TOTAL # HOPS : 18351
TOTAL # BITS WHICH HOPPED : 13115
TOTAL # ROWS WHICH HAD A HOPPER: 244
TOTAL # COLS WHICH HAD A HOPPER: 256

Vendor 1
S/N 124

#HOPS	#BITS	HOP	#HOPS	HOP	#HOPS	DURATION	#HOPS
0	0	+ 0	0	- 0	0	0	0
1	9118	+ 1	0	- 1	0	1	2812
2	3081	+ 2	0	- 2	0	2	52
3	661	+ 3	8245	- 3	9667	3	26
4	200	+ 4	233	- 4	201	4	79
5	42	+ 5	5	- 5	0	5	118
6	13	+ 6	0	- 6	0	6	103
7	0	+ 7	0	- 7	0	7	198
8	0	+ 8	0	- 8	0	8	53
9	0	+ 9	0	- 9	0	9	60
10	0	+ 10	0	- 10	0	10	74
11	0	+ 11	0	- 11	0	11	99
12	0	+ 12	0	- 12	0	12	70
13	0	+ 13	0	- 13	0	13	114
14	0	+ 14	0	- 14	0	14	92
15	0	+ 15	0	- 15	0	15	14
16	0	+ 16	0	- 16	0	16	21
17	0	+ 17	0	- 17	0	17	31
18	0	+ 18	0	- 18	0	18	63
19	0	+ 19	0	- 19	0	19	54
20	0	+ 20	0	- 20	0	20	87
21	0	+ 21	0	- 21	0	21	77
22	0	+ 22	0	- 22	0	22	31
23	0	+ 23	0	- 23	0	23	29
24	0	+ 24	0	- 24	0	24	23
25	0	+ 25	0	- 25	0	25	58
26	0	+ 26	0	- 26	0	26	28
27	0	+ 27	0	- 27	0	27	54
28	0	+ 28	0	- 28	0	28	101
29	0	+ 29	0	- 29	0	29	13
30	0	+ 30	0	- 30	0	30	14
31	0	+ 31	0	- 31	0	31	69
32	0	+ 32	0	- 32	0	32	26
33	0	+ 33	0	- 33	0	33	17
34	0	+ 34	0	- 34	0	34	22
35	0	+ 35	0	- 35	0	35	10
36	0	+ 36	0	- 36	0	36	21
37	0	+ 37	0	- 37	0	37	8
38	0	+ 38	0	- 38	0	38	31
39	0	+ 39	0	- 39	0	39	6
40	0	+ 40	0	- 40	0	40	10
41	0	+ 41	0	- 41	0	41	2
42	0	+ 42	0	- 42	0	42	9
43	0	+ 43	0	- 43	0	43	6
44	0	+ 44	0	- 44	0	44	0
45	0	+ 45	0	- 45	0	45	0
46	0	+ 46	0	- 46	0	46	7
47	0	+ 47	0	- 47	0	47	17

48	0	+ 48	0	- 48	0	48	20
49	0	+ 49	0	- 49	0	49	3
50	0	+ 50	0	- 50	0	50	8
51	0	+ 51	0	- 51	0	51	1
52	0	+ 52	0	- 52	0	52	1
53	0	+ 53	0	- 53	0	53	6
54	0	+ 54	0	- 54	0	54	1
55	0	+ 55	0	- 55	0	55	3
56	0	+ 56	0	- 56	0	56	1
57	0	+ 57	0	- 57	0	57	1
58	0	+ 58	0	- 58	0	58	3
59	0	+ 59	0	- 59	0	59	0
60	0	+ 60	0	- 60	0	60	0
61	0	+ 61	0	- 61	0	61	0
62	0	+ 62	0	- 62	0	62	0
63	0	+ 63	0	- 63	0	63	0
64	0	+ 64	0	- 64	0	64	0
65	0	+ 65	0	- 65	0	65	0
66	0	+ 66	0	- 66	0	66	0
67	0	+ 67	0	- 67	0	67	0
68	0	+ 68	0	- 68	0	68	0
69	0	+ 69	0	- 69	0	69	0
70	0	+ 70	0	- 70	0	70	0
71	0	+ 71	0	- 71	0	71	0
72	0	+ 72	0	- 72	0	72	0
73	0	+ 73	0	- 73	0	73	0
74	0	+ 74	0	- 74	0	74	0
75	0	+ 75	0	- 75	0	75	0
76	0	+ 76	0	- 76	0	76	0
77	0	+ 77	0	- 77	0	77	0
78	0	+ 78	0	- 78	0	78	0
79	0	+ 79	0	- 79	0	79	0
80	0	+ 80	0	- 80	0	80	0
81	0	+ 81	0	- 81	0	81	0
82	0	+ 82	0	- 82	0	82	0
83	0	+ 83	0	- 83	0	83	0
84	0	+ 84	0	- 84	0	84	0
85	0	+ 85	0	- 85	0	85	0
86	0	+ 86	0	- 86	0	86	0
87	0	+ 87	0	- 87	0	87	0
88	0	+ 88	0	- 88	0	88	0
89	0	+ 89	0	- 89	0	89	0
90	0	+ 90	0	- 90	0	90	0
91	0	+ 91	0	- 91	0	91	0
92	0	+ 92	0	- 92	0	92	0
93	0	+ 93	0	- 93	0	93	0
94	0	+ 94	0	- 94	0	94	0
95	0	+ 95	0	- 95	0	95	0
96	0	+ 96	0	- 96	0	96	0
97	0	+ 97	0	- 97	0	97	0
98	0	+ 98	0	- 98	0	98	0
99	0	+ 99	0	- 99	0	99	0
100	0	+ 100	0	- 100	0	100	0
101	0	+ 101	0	- 101	0	101	0

H FILES 2 TO 60 INDIV AND CUM M,S OF #H VS H Vendor 1
+ BINNED DIFFERENCE MAGNITUDES (EXCLUDING PUMPED ROWS) S/N 124

0:	2106547	737544	107584	10040	208	0	0	0	0	0
10:	0	0	0	0	0	0	0	0	0	0
20:	0	0	0	0	0	0	0	0	0	0
30:	0	0	0	0	0	0	0	0	0	0
40:	0	0	0	0	0	0	0	0	0	0
50:	0	0	0	0	0	0	0	0	0	0
60:	0	0	0	0	0	0	0	0	0	0
70:	0	0	0	0	0	0	0	0	0	0
80:	0	0	0	0	0	0	0	0	0	0
90:	0	0	0	0	0	0	0	0	0	0
100:	0	0								

- BINNED DIFFERENCE MAGNITUDES (EXCLUDING R0 AND R128)

0:	112252	9424	314	5	0	0	0	0	0
10:	0	0	0	0	0	0	0	0	0
20:	0	0	0	0	0	0	0	0	0
30:	0	0	0	0	0	0	0	0	0
40:	0	0	0	0	0	0	0	0	0
50:	0	0	0	0	0	0	0	0	0
60:	0	0	0	0	0	0	0	0	0
70:	0	0	0	0	0	0	0	0	0
80:	0	0	0	0	0	0	0	0	0
90:	0	0	0	0	0	0	0	0	0
100:	0								

```
 0 M=-5.966767E-03 S= .8157448 #= 3836416
 2 M=-.3869494 S= .7039402 #= 65024
 3 M= .1865465 S= .7816269 #= 65024
 4 M=-.4186454 S= .7755871 #= 65024
 5 M= 8.718319E-02 S= .8097642 #= 65024
 6 M= 7.857099E-02 S= .6714761 #= 65024
 7 M=-.2270392 S= .7648405 #= 65024
 8 M= .2294076 S= .7491536 #= 65024
 9 M= .3111159 S= .7804941 #= 65024
 10 M= .218427 S= .6939697 #= 65024
 11 M=-.2338983 S= .7232364 #= 65024
 12 M=-7.634104E-02 S= .6687618 #= 65024
 13 M=-1.070066 S= .6851387 #= 65024
 14 M= .8983914 S= .6815253 #= 65024
 15 M= .1657542 S= .7237664 #= 65024
 16 M= .1527744 S= .7571318 #= 65024
 17 M= 2.968135E-02 S= .6679527 #= 65024
 18 M= 4.264579E-02 S= .7138306 #= 65024
 19 M=-.1325203 S= .7480868 #= 65024
 20 M=-1.600947E-02 S= .6148376 #= 65024
 21 M=-.4333938 S= .8360295 #= 65024
 22 M= .4941099 S= .8158095 #= 65024
 23 M= .17918 S= .8465577 #= 65024
 24 M= .0925812 S= .7118017 #= 65024
 25 M= 3.546383E-02 S= .7475639 #= 65024
 26 M=-.2221487 S= .7434157 #= 65024
```

```
27 M=-7.378814E-02 S= .715952 #= 65024
28 M= 4.224594E-02 S= .7599156 #= 65024
29 M= 6.692913E-02 S= .7945411 #= 65024
30 M= 7.769439E-02 S= .8344457 #= 65024
31 M=-.2116142 S= .7296779 #= 65024
32 M= .1999416 S= .7249559 #= 65024
33 M=-.2671936 S= .816168 #= 65024
34 M= .3021654 S= .8713173 #= 65024
35 M=-.5400314 S= .8978201 #= 65024
36 M= .2863558 S= .7585495 #= 65024
37 M= .3309701 S= .7382063 #= 65024
38 M= .2627338 S= .686335 #= 65024
39 M=-.6485605 S= .7279129 #= 65024
40 M= .1169876 S= .846028 #= 65024
41 M=-.1871463 S= .8017753 #= 65024
42 M= .2182117 S= .7618746 #= 65024
43 M= 2.065391E-02 S= .8291186 #= 65024
44 M= .206493 S= .8866041 #= 65024
45 M=-.3767225 S= .7833036 #= 65024
46 M= 3.000431E-02 S= .7777141 #= 65024
47 M= .1825787 S= .7556688 #= 65024
48 M= .2286387 S= .7287884 #= 65024
49 M= .2576741 S= .7965413 #= 65024
50 M=-.400283 S= .8184603 #= 65024
51 M= 2.802042E-02 S= .7544724 #= 65024
52 M=-7.849409E-02 S= .738989 #= 65024
53 M=-.1609406 S= .8134214 #= 65024
54 M= .2811116 S= .7380435 #= 65024
55 M=-.121063 S= .6439238 #= 65024
56 M= .2456478 S= .7087336 #= 65024
57 M=-.2118449 S= .7524505 #= 65024
58 M= 3.229577E-03 S= .6208983 #= 65024
59 M=-.1449926 S= .7122806 #= 65024
```

TOTAL # HOPS : 18866
TOTAL # BITS WHICH HOPPED : 13368
TOTAL # ROWS WHICH HAD A HOPPER: 242
TOTAL # COLS WHICH HAD A HOPPER: 256

Vendor 1
S/N 125

#HOPS	#BITS	HOP	#HOPS	HOP	#HOPS	DURATION	#HOPS
0	0	+ 0	0	- 0	0	0	0
1	9161	+ 1	0	- 1	0	1	2944
2	3270	+ 2	0	- 2	0	2	79
3	671	+ 3	8794	- 3	9630	3	53
4	210	+ 4	248	- 4	190	4	58
5	37	+ 5	4	- 5	0	5	105
6	10	+ 6	0	- 6	0	6	172
7	7	+ 7	0	- 7	0	7	191
8	1	+ 8	0	- 8	0	8	89
9	0	+ 9	0	- 9	0	9	69
10	1	+ 10	0	- 10	0	10	96
11	0	+ 11	0	- 11	0	11	110
12	0	+ 12	0	- 12	0	12	70
13	0	+ 13	0	- 13	0	13	136
14	0	+ 14	0	- 14	0	14	71
15	0	+ 15	0	- 15	0	15	29
16	0	+ 16	0	- 16	0	16	31
17	0	+ 17	0	- 17	0	17	37
18	0	+ 18	0	- 18	0	18	33
19	0	+ 19	0	- 19	0	19	35
20	0	+ 20	0	- 20	0	20	73
21	0	+ 21	0	- 21	0	21	62
22	0	+ 22	0	- 22	0	22	33
23	0	+ 23	0	- 23	0	23	45
24	0	+ 24	0	- 24	0	24	21
25	0	+ 25	0	- 25	0	25	51
26	0	+ 26	0	- 26	0	26	16
27	0	+ 27	0	- 27	0	27	38
28	0	+ 28	0	- 28	0	28	97
29	0	+ 29	0	- 29	0	29	42
30	0	+ 30	0	- 30	0	30	44
31	0	+ 31	0	- 31	0	31	78
32	0	+ 32	0	- 32	0	32	19
33	0	+ 33	0	- 33	0	33	14
34	0	+ 34	0	- 34	0	34	27
35	0	+ 35	0	- 35	0	35	6
36	0	+ 36	0	- 36	0	36	19
37	0	+ 37	0	- 37	0	37	26
38	0	+ 38	0	- 38	0	38	18
39	0	+ 39	0	- 39	0	39	8
40	0	+ 40	0	- 40	0	40	9
41	0	+ 41	0	- 41	0	41	1
42	0	+ 42	0	- 42	0	42	11
43	0	+ 43	0	- 43	0	43	7
44	0	+ 44	0	- 44	0	44	0
45	0	+ 45	0	- 45	0	45	5
46	0	+ 46	0	- 46	0	46	15
47	0	+ 47	0	- 47	0	47	14

48	0	+ 48	0	- 48	0	48	21
49	0	+ 49	0	- 49	0	49	1
50	0	+ 50	0	- 50	0	50	2
51	0	+ 51	0	- 51	0	51	2
52	0	+ 52	0	- 52	0	52	2
53	0	+ 53	0	- 53	0	53	9
54	0	+ 54	0	- 54	0	54	7
55	0	+ 55	0	- 55	0	55	3
56	0	+ 56	0	- 56	0	56	7
57	0	+ 57	0	- 57	0	57	0
58	0	+ 58	0	- 58	0	58	0
59	0	+ 59	0	- 59	0	59	0
60	0	+ 60	0	- 60	0	60	0
61	0	+ 61	0	- 61	0	61	0
62	0	+ 62	0	- 62	0	62	0
63	0	+ 63	0	- 63	0	63	0
64	0	+ 64	0	- 64	0	64	0
65	0	+ 65	0	- 65	0	65	0
66	0	+ 66	0	- 66	0	66	0
67	0	+ 67	0	- 67	0	67	0
68	0	+ 68	0	- 68	0	68	0
69	0	+ 69	0	- 69	0	69	0
70	0	+ 70	0	- 70	0	70	0
71	0	+ 71	0	- 71	0	71	0
72	0	+ 72	0	- 72	0	72	0
73	0	+ 73	0	- 73	0	73	0
74	0	+ 74	0	- 74	0	74	0
75	0	+ 75	0	- 75	0	75	0
76	0	+ 76	0	- 76	0	76	0
77	0	+ 77	0	- 77	0	77	0
78	0	+ 78	0	- 78	0	78	0
79	0	+ 79	0	- 79	0	79	0
80	0	+ 80	0	- 80	0	80	0
81	0	+ 81	0	- 81	0	81	0
82	0	+ 82	0	- 82	0	82	0
83	0	+ 83	0	- 83	0	83	0
84	0	+ 84	0	- 84	0	84	0
85	0	+ 85	0	- 85	0	85	0
86	0	+ 86	0	- 86	0	86	0
87	0	+ 87	0	- 87	0	87	0
88	0	+ 88	0	- 88	0	88	0
89	0	+ 89	0	- 89	0	89	0
90	0	+ 90	0	- 90	0	90	0
91	0	+ 91	0	- 91	0	91	0
92	0	+ 92	0	- 92	0	92	0
93	0	+ 93	0	- 93	0	93	0
94	0	+ 94	0	- 94	0	94	0
95	0	+ 95	0	- 95	0	95	0
96	0	+ 96	0	- 96	0	96	0
97	0	+ 97	0	- 97	0	97	0
98	0	+ 98	0	- 98	0	98	0
99	0	+ 99	0	- 99	0	99	0
100	0	+ 100	0	- 100	0	100	0
101	0	+ 101	0	- 101	0	101	0

H FILES 2 TO 60 INDIV AND CUM M,S OF #H VS H Vendor 1
+ BINNED DIFFERENCE MAGNITUDES (EXCLUDING PUMPED ROWS) S/N 125

0:	2125578	722715	105506	9704	194	1	0	0	0	0
10:	0	0	0	0	0	0	0	0	0	0
20:	0	0	0	0	0	0	0	0	0	0
30:	0	0	0	0	0	0	0	0	0	0
40:	0	0	0	0	0	0	0	0	0	0
50:	0	0	0	0	0	0	0	0	0	0
60:	0	0	0	0	0	0	0	0	0	0
70:	0	0	0	0	0	0	0	0	0	0
80:	0	0	0	0	0	0	0	0	0	0
90:	0	0	0	0	0	0	0	0	0	0
100:	0	0								

- BINNED DIFFERENCE MAGNITUDES (EXCLUDING R0 AND R128)

0:		107331	9267	273	5	0	0	0	0	0
10:	0	0	0	0	0	0	0	0	0	0
20:	0	0	0	0	0	0	0	0	0	0
30:	0	0	0	0	0	0	0	0	0	0
40:	0	0	0	0	0	0	0	0	0	0
50:	0	0	0	0	0	0	0	0	0	0
60:	0	0	0	0	0	0	0	0	0	0
70:	0	0	0	0	0	0	0	0	0	0
80:	0	0	0	0	0	0	0	0	0	0
90:	0	0	0	0	0	0	0	0	0	0
100:	0									

0 M=-9.332147E-03 S= .808528 #= 3836416
2 M=-.416477 S= .6954718 #= 65024
3 M= 2.277621E-02 S= .7716872 #= 65024
4 M=-.3529466 S= .7677572 #= 65024
5 M= .1594796 S= .7847394 #= 65024
6 M= 6.453002E-02 S= .6908885 #= 65024
7 M=-.2160126 S= .7469019 #= 65024
8 M= .1468073 S= .7045474 #= 65024
9 M= .304626 S= .7816148 #= 65024
10 M= .1979577 S= .712139 #= 65024
11 M=-.2519531 S= .7534352 #= 65024
12 M=-2.906619E-02 S= .6754665 #= 65024
13 M=-.9727947 S= .6813132 #= 65024
14 M= .810347 S= .7056448 #= 65024
15 M= .1243848 S= .7196373 #= 65024
16 M= .1927442 S= .7442973 #= 65024
17 M= 8.38152E-03 S= .6703856 #= 65024
18 M=-3.429503E-03 S= .7250692 #= 65024
19 M=-1.599409E-02 S= .7622437 #= 65024
20 M= 5.135027E-02 S= .6397371 #= 65024
21 M=-.5524268 S= .7966341 #= 65024
22 M= .4226593 S= .82538 #= 65024
23 M= .2921998 S= .8663357 #= 65024
24 M= 5.539493E-02 S= .7167947 #= 65024

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25 M=-3.835507E-02 S= .7744631 #= 65024
26 M=-.1325049 S= .7548737 #= 65024
27 M=-.1161264 S= .7149005 #= 65024
28 M=-1.537894E-05 S= .7404405 #= 65024
29 M= .0359252 S= .7590159 #= 65024
30 M= .1288601 S= .7953783 #= 65024
31 M=-.1585722 S= .7458105 #= 65024
32 M= .1607868 S= .7533405 #= 65024
33 M=-.2826649 S= .8019 #= 65024
34 M= .1954201 S= .837686 #= 65024
35 M=-.3312623 S= .8790452 #= 65024
36 M= .2139979 S= .7237846 #= 65024
37 M= .3807517 S= .7424354 #= 65024
38 M= .2203802 S= .7089146 #= 65024
39 M=-.6070989 S= .7311515 #= 65024
40 M= 3.875492E-03 S= .8060166 #= 65024
41 M=-.1517286 S= .7568749 #= 65024
42 M= .199311 S= .7426382 #= 65024
43 M=-3.594058E-02 S= .8356016 #= 65024
44 M= .3272484 S= .9138277 #= 65024
45 M=-.3029497 S= .8106415 #= 65024
46 M=-7.770977E-02 S= .7658564 #= 65024
47 M= .2369125 S= .7525376 #= 65024
48 M= .1440853 S= .7449141 #= 65024
49 M= .3755844 S= .8091251 #= 65024
50 M=-.5551488 S= .8392308 #= 65024
51 M= .1006705 S= .7855896 #= 65024
52 M=-.1546044 S= .7523475 #= 65024
53 M=-6.036233E-02 S= .8031787 #= 65024
54 M= .3084707 S= .7131835 #= 65024
55 M=-.1640164 S= .6483126 #= 65024
56 M= .169276 S= .7293996 #= 65024
57 M=-9.005906E-02 S= .7731143 #= 65024
58 M= 6.105438E-03 S= .6064793 #= 65024
59 M=-.1761965 S= .6758904 #= 65024
```

TOTAL # HOPS : 21456
TOTAL # BITS WHICH HOPPED : 14563
TOTAL # ROWS WHICH HAD A HOPPER: 246
TOTAL # COLS WHICH HAD A HOPPER: 256

Vendor 1
S/N 126

#HOPS	#BITS	HOP	#HOPS	HOP	#HOPS	DURATION	#HOPS
0	0	+ 0	0	- 0	0	0	0
1	9573	+ 1	0	- 1	0	1	3612
2	3713	+ 2	0	- 2	0	2	98
3	827	+ 3	10114	- 3	10726	3	67
4	342	+ 4	318	- 4	284	4	113
5	75	+ 5	5	- 5	8	5	153
6	22	+ 6	1	- 6	0	6	204
7	4	+ 7	0	- 7	0	7	248
8	2	+ 8	0	- 8	0	8	98
9	[illegible]	+ 9	0	- 9	0	9	91
10	1	+ 10	0	- 10	0	10	111
11	0	+ 11	0	- 11	0	11	106
12	0	+ 12	0	- 12	0	12	90
13	0	+ 13	0	- 13	0	13	147
14	1	+ 14	0	- 14	0	14	68
15	1	+ 15	0	- 15	0	15	26
16	0	+ 16	0	- 16	0	16	51
17	0	+ 17	0	- 17	0	17	61
18	0	+ 18	0	- 18	0	18	66
19	0	+ 19	0	- 19	0	19	39
20	0	+ 20	0	- 20	0	20	87
21	0	+ 21	0	- 21	0	21	107
22	0	+ 22	0	- 22	0	22	48
23	0	+ 23	0	- 23	0	23	36
24	0	+ 24	0	- 24	0	24	50
25	0	+ 25	0	- 25	0	25	40
26	0	+ 26	0	- 26	0	26	29
27	0	+ 27	0	- 27	0	27	46
28	0	+ 28	0	- 28	0	28	116
29	0	+ 29	0	- 29	0	29	73
30	0	+ 30	0	- 30	0	30	40
31	0	+ 31	0	- 31	0	31	74
32	0	+ 32	0	- 32	0	32	25
33	0	+ 33	0	- 33	0	33	13
34	0	+ 34	0	- 34	0	34	49
35	0	+ 35	0	- 35	0	35	17
36	0	+ 36	0	- 36	0	36	16
37	0	+ 37	0	- 37	0	37	18
38	0	+ 38	0	- 38	0	38	22
39	0	+ 39	0	- 39	0	39	11
40	0	+ 40	0	- 40	0	40	14
41	0	+ 41	0	- 41	0	41	5
42	0	+ 42	0	- 42	0	42	9
43	0	+ 43	0	- 43	0	43	13
44	0	+ 44	0	- 44	0	44	2
45	0	+ 45	0	- 45	0	45	9
46	0	+ 46	0	- 46	0	46	20
47	0	+ 47	0	- 47	0	47	17

48	0	+ 48	0	- 48	0	48	13
49	0	+ 49	0	- 49	0	49	7
50	0	+ 50	0	- 50	0	50	19
51	0	+ 51	0	- 51	0	51	0
52	0	+ 52	0	- 52	0	52	2
53	0	+ 53	0	- 53	0	53	9
54	0	+ 54	0	- 54	0	54	13
55	0	+ 55	0	- 55	0	55	2
56	0	+ 56	0	- 56	0	56	6
57	0	+ 57	0	- 57	0	57	1
58	0	+ 58	0	- 58	0	58	0
59	0	+ 59	0	- 59	0	59	0
60	0	+ 60	0	- 60	0	60	0
61	0	+ 61	0	- 61	0	61	0
62	0	+ 62	0	- 62	0	62	0
63	0	+ 63	0	- 63	0	63	0
64	0	+ 64	0	- 64	0	64	0
65	0	+ 65	0	- 65	0	65	0
66	0	+ 66	0	- 66	0	66	0
67	0	+ 67	0	- 67	0	67	0
68	0	+ 68	0	- 68	0	68	0
69	0	+ 69	0	- 69	0	69	0
70	0	+ 70	0	- 70	0	70	0
71	0	+ 71	0	- 71	0	71	0
72	0	+ 72	0	- 72	0	72	0
73	0	+ 73	0	- 73	0	73	0
74	0	+ 74	0	- 74	0	74	0
75	0	+ 75	0	- 75	0	75	0
76	0	+ 76	0	- 76	0	76	0
77	0	+ 77	0	- 77	0	77	0
78	0	+ 78	0	- 78	0	78	0
79	0	+ 79	0	- 79	0	79	0
80	0	+ 80	0	- 80	0	80	0
81	0	+ 81	0	- 81	0	81	0
82	0	+ 82	0	- 82	0	82	0
83	0	+ 83	0	- 83	0	83	0
84	0	+ 84	0	- 84	0	84	0
85	0	+ 85	0	- 85	0	85	0
86	0	+ 86	0	- 86	0	86	0
87	0	+ 87	0	- 87	0	87	0
88	0	+ 88	0	- 88	0	88	0
89	0	+ 89	0	- 89	0	89	0
90	0	+ 90	0	- 90	0	90	0
91	0	+ 91	0	- 91	0	91	0
92	0	+ 92	0	- 92	0	92	0
93	0	+ 93	0	- 93	0	93	0
94	0	+ 94	0	- 94	0	94	0
95	0	+ 95	0	- 95	0	95	0
96	0	+ 96	0	- 96	0	96	0
97	0	+ 97	0	- 97	0	97	0
98	0	+ 98	0	- 98	0	98	0
99	0	+ 99	0	- 99	0	99	0
100	0	+ 100	0	- 100	0	100	0
101	0	+ 101	0	- 101	0	101	0

H FILES 2 TO 60 INDIV AND CUM M,S OF #H VS H Vendor 1
+ BINNED DIFFERENCE MAGNITUDES (EXCLUDING PUMPED ROWS) S/N 126

0:	2130032	718363	104894	10729	284	8	0	0	0	0
10:	0	0	0	0	0	0	0	0	0	0
20:	0	0	0	0	0	0	0	0	0	0
30:	0	0	0	0	0	0	0	0	0	0
40:	0	0	0	0	0	0	0	0	0	0
50:	0	0	0	0	0	0	0	0	0	0
60:	0	0	0	0	0	0	0	0	0	0
70:	0	0	0	0	0	0	0	0	0	0
80:	0	0	0	0	0	0	0	0	0	0
90:	0	0	0	0	0	0	0	0	0	0
100:	0	0								

- BINNED DIFFERENCE MAGNITUDES (EXCLUDING R0 AND R128)

0:		106241	10578	345	5	1	0	0	0	0
10:	0	0	0	0	0	0	0	0	0	0
20:	0	0	0	0	0	0	0	0	0	0
30:	0	0	0	0	0	0	0	0	0	0
40:	0	0	0	0	0	0	0	0	0	0
50:	0	0	0	0	0	0	0	0	0	0
60:	0	0	0	0	0	0	0	0	0	0
70:	0	0	0	0	0	0	0	0	0	0
80:	0	0	0	0	0	0	0	0	0	0
90:	0	0	0	0	0	0	0	0	0	0
100:	0									

```
 0 M=-1.017851E-02 S= .8104115 #= 3836416
 2 M=-.3894408 S= .6965854 #= 65024
 3 M=-1.433317E-02 S= .77192 #= 65024
 4 M=-.3408126 S= .7635629 #= 65024
 5 M= .1487297 S= .7870137 #= 65024
 6 M= .081047 S= .6850501 #= 65024
 7 M=-.2385427 S= .7570975 #= 65024
 8 M= .1327664 S= .721823 #= 65024
 9 M= .2977824 S= .7899823 #= 65024
 10 M= .1975578 S= .7217733 #= 65024
 11 M=-.2485236 S= .7638409 #= 65024
 12 M=-2.294537E-02 S= .6745859 #= 65024
 13 M=-.9078802 S= .6799498 #= 65024
 14 M= .7537678 S= .707249 #= 65024
 15 M= .1081139 S= .7092183 #= 65024
 16 M= .1989266 S= .7563549 #= 65024
 17 M= 1.016548E-02 S= .6671183 #= 65024
 18 M= 1.674766E-02 S= .7265157 #= 65024
 19 M=-2.100763E-02 S= .7705507 #= 65024
 20 M= 5.278051E-02 S= .6343938 #= 65024
 21 M=-.5524268 S= .8136532 #= 65024
 22 M= .4201987 S= .8245118 #= 65024
 23 M= .2732683 S= .8624133 #= 65024
 24 M= 7.165047E-02 S= .7171456 #= 65024
```

```
25 M=-3.909326E-02 S= .7849787 #= 65024
26 M=-.1424243 S= .7612609 #= 65024
27 M=-.1190637 S= .7076797 #= 65024
28 M=-8.658341E-03 S= .7502736 #= 65024
29 M= 3.278789E-02 S= .7652513 #= 65024
30 M= .1375338 S= .8054441 #= 65024
31 M=-.1598948 S= .7473207 #= 65024
32 M= .1585568 S= .7580143 #= 65024
33 M=-.2931225 S= .8097484 #= 65024
34 M= .2142747 S= .8481379 #= 65024
35 M=-.348379 S= .9065596 #= 65024
36 M= .2206877 S= .7324017 #= 65024
37 M= .3623739 S= .7443494 #= 65024
38 M= .2394501 S= .7259756 #= 65024
39 M=-.6113127 S= .7342806 #= 65024
40 M= 3.352608E-03 S= .8192288 #= 65024
41 M=-.1695682 S= .7590995 #= 65024
42 M= .2292846 S= .7459408 #= 65024
43 M=-3.108083E-02 S= .8307394 #= 65024
44 M= .3185132 S= .9095666 #= 65024
45 M=-.2967366 S= .8348508 #= 65024
46 M=-6.119279E-02 S= .7742562 #= 65024
47 M= .220088 S= .7563491 #= 65024
48 M= .1418707 S= .7409725 #= 65024
49 M= .3669722 S= .8136913 #= 65024
50 M=-.5470903 S= .843577 #= 65024
51 M= 8.466105E-02 S= .7881493 #= 65024
52 M=-.1333508 S= .7504231 #= 65024
53 M=-7.080463E-02 S= .8150011 #= 65024
54 M= .2864173 S= .7224079 #= 65024
55 M=-.1737051 S= .6489911 #= 65024
56 M= .1747355 S= .7311567 #= 65024
57 M=-.1065607 S= .7868183 #= 65024
58 M= 1.268762E-02 S= .6081754 #= 65024
59 M=-.1701987 S= .6784465 #= 65024
```

TOTAL # HOPS : -11190
TOTAL # BITS WHICH HOPPED : 17969
TOTAL # ROWS WHICH HAD A HOPPER: 254
TOTAL # COLS WHICH HAD A HOPPER: 256

Vendor 2
S/N 326

#HOPS	#BITS	HOP	#HOPS	HOP	#HOPS	DURATION	#HOPS
0	0	+ 0	0	- 0	0	0	0
1	7538	+ 1	0	- 1	0	1	12057
2	4166	+ 2	0	- 2	0	2	3011
3	1941	+ 3	19703	- 3	20897	3	2114
4	1159	+ 4	4776	- 4	4923	4	1645
5	752	+ 5	1396	- 5	1386	5	1367
6	552	+ 6	434	- 6	406	6	1220
7	390	+ 7	124	- 7	147	7	1009
8	273	+ 8	49	- 8	50	8	847
9	227	+ 9	17	- 9	16	9	707
10	182	+ 10	9	- 10	7	10	585
11	151	+ 11	0	- 11	3	11	555
12	116	+ 12	1	- 12	1	12	490
13	89	+ 13	1	- 13	0	13	458
14	75	+ 14	0	- 14	0	14	368
15	57	+ 15	0	- 15	0	15	360
16	52	+ 16	0	- 16	0	16	296
17	48	+ 17	0	- 17	0	17	256
18	48	+ 18	0	- 18	0	18	327
19	26	+ 19	0	- 19	0	19	272
20	22	+ 20	0	- 20	0	20	308
21	15	+ 21	0	- 21	0	21	239
22	20	+ 22	0	- 22	0	22	219
23	19	+ 23	0	- 23	0	23	189
24	9	+ 24	0	- 24	0	24	186
25	7	+ 25	0	- 25	0	25	148
26	7	+ 26	0	- 26	0	26	124
27	3	+ 27	0	- 27	0	27	227
28	8	+ 28	0	- 28	0	28	163
29	6	+ 29	0	- 29	0	29	143
30	2	+ 30	0	- 30	0	30	151
31	1	+ 31	0	- 31	0	31	119
32	3	+ 32	0	- 32	0	32	127
33	2	+ 33	0	- 33	0	33	100
34	1	+ 34	0	- 34	0	34	98
35	0	+ 35	0	- 35	0	35	81
36	0	+ 36	0	- 36	0	36	185
37	1	+ 37	0	- 37	0	37	130
38	0	+ 38	0	- 38	0	38	126
39	1	+ 39	0	- 39	0	39	96
40	0	+ 40	0	- 40	0	40	64
41	0	+ 41	0	- 41	0	41	62
42	0	+ 42	0	- 42	0	42	70
43	0	+ 43	0	- 43	0	43	52
44	0	+ 44	0	- 44	0	44	51
45	0	+ 45	0	- 45	0	45	124
46	0	+ 46	0	- 46	0	46	73
47	0	+ 47	0	- 47	0	47	77

48	0	+ 48	0	- 48	0	48	77
49	0	+ 49	0	- 49	0	49	67
50	0	+ 50	0	- 50	0	50	47
51	0	+ 51	0	- 51	0	51	50
52	0	+ 52	0	- 52	0	52	43
53	0	+ 53	0	- 53	0	53	38
54	0	+ 54	0	- 54	0	54	119
55	0	+ 55	0	- 55	0	55	39
56	0	+ 56	0	- 56	0	56	16
57	0	+ 57	0	- 57	0	57	4
58	0	+ 58	0	- 58	0	58	5
59	0	+ 59	0	- 59	0	59	0
60	0	+ 60	0	- 60	0	60	0
61	0	+ 61	0	- 61	0	61	0
62	0	+ 62	0	- 62	0	62	0
63	0	+ 63	0	- 63	0	63	0
64	0	+ 64	0	- 64	0	64	0
65	0	+ 65	0	- 65	0	65	0
66	0	+ 66	0	- 66	0	66	0
67	0	+ 67	0	- 67	0	67	0
68	0	+ 68	0	- 68	0	68	0
69	0	+ 69	0	- 69	0	69	0
70	0	+ 70	0	- 70	0	70	0
71	0	+ 71	0	- 71	0	71	0
72	0	+ 72	0	- 72	0	72	0
73	0	+ 73	0	- 73	0	73	0
74	0	+ 74	0	- 74	0	74	0
75	0	+ 75	0	- 75	0	75	0
76	0	+ 76	0	- 76	0	76	0
77	0	+ 77	0	- 77	0	77	0
78	0	+ 78	0	- 78	0	78	0
79	0	+ 79	0	- 79	0	79	0
80	0	+ 80	0	- 80	0	80	0
81	0	+ 81	0	- 81	0	81	0
82	0	+ 82	0	- 82	0	82	0
83	0	+ 83	0	- 83	0	83	0
84	0	+ 84	0	- 84	0	84	0
85	0	+ 85	0	- 85	0	85	0
86	0	+ 86	0	- 86	0	86	0
87	0	+ 87	0	- 87	0	87	0
88	0	+ 88	0	- 88	0	88	0
89	0	+ 89	0	- 89	0	89	0
90	0	+ 90	0	- 90	0	90	0
91	0	+ 91	0	- 91	0	91	0
92	0	+ 92	0	- 92	0	92	0
93	0	+ 93	0	- 93	0	93	0
94	0	+ 94	0	- 94	0	94	0
95	0	+ 95	0	- 95	0	95	0
96	0	+ 96	0	- 96	0	96	0
97	0	+ 97	0	- 97	0	97	0
98	0	+ 98	0	- 98	0	98	0
99	0	+ 99	0	- 99	0	99	0
100	0	+ 100	0	- 100	0	100	0
101	0	+ 101	0	- 101	0	101	0

H FILES 2 TO 60 INDIV AND CUM M,S OF #H VS H Vendor 2
+ BINNED DIFFERENCE MAGNITUDES (EXCLUDING PUMPED ROWS) S/N 326

0:	2016622	770501	110315	22031	5186	1467	429	160	51	16
10:	7	3	1	0	0	0	0	0	0	0
20:	0	0	0	0	0	0	0	0	0	0
30:	0	0	0	0	0	0	0	0	0	0
40:	0	0	0	0	0	0	0	0	0	0
50:	0	0	0	0	0	0	0	0	0	0
60:	0	0	0	0	0	0	0	0	0	0
70:	0	0	0	0	0	0	0	0	0	0
80:	0	0	0	0	0	0	0	0	0	0
90:	0	0	0	0	0	0	0	0	0	0
100:	0	0								

- BINNED DIFFERENCE MAGNITUDES (EXCLUDING R0 AND R128)

0:	104951	20659	5015	1442	458	129	52	17	9
10:	0	1	1	0	0	0	0	0	0	0
20:	0	0	0	0	0	0	0	0	0	0
30:	0	0	0	0	0	0	0	0	0	0
40:	0	0	0	0	0	0	0	0	0	0
50:	0	0	0	0	0	0	0	0	0	0
60:	0	0	0	0	0	0	0	0	0	0
70:	0	0	0	0	0	0	0	0	0	0
80:	0	0	0	0	0	0	0	0	0	0
90:	0	0	0	0	0	0	0	0	0	0
100:	0									

0 M= 2.420749E-03 S= .8969347 #= 3836416
2 M=-4.762857E-02 S= .9456372 #= 65024
3 M=-.1653082 S= .8885766 #= 65024
4 M=-.0437377 S= .9341186 #= 65024
5 M=-4.163078E-02 S= .8641326 #= 65024
6 M= 3.414124E-02 S= .8546291 #= 65024
7 M= 3.444882E-02 S= .850757 #= 65024
8 M= .1731976 S= .9384045 #= 65024
9 M= 6.286909E-02 S= .9279355 #= 65024
10 M=-.1901759 S= .8642036 #= 65024
11 M= 7.049705E-02 S= .9062853 #= 65024
12 M= 7.377276E-02 S= .9445438 #= 65024
13 M=-.4759935 S= .9143581 #= 65024
14 M= .2293922 S= .8553322 #= 65024
15 M= 5.145792E-02 S= .8473607 #= 65024
16 M= .1259843 S= .8554181 #= 65024
17 M= .2627799 S= .8430397 #= 65024
18 M=-.1804872 S= .8729638 #= 65024
19 M= 1.865465E-02 S= .8974995 #= 65024
20 M= 1.402559E-02 S= .9057792 #= 65024
21 M=-4.183071E-02 S= 1.045305 #= 65024
22 M= .2694697 S= .8695265 #= 65024
23 M= 3.521777E-02 S= .9100152 #= 65024
24 M= 2.060778E-02 S= .8516383 #= 65024

```
25 M=-.1266609 S= .8178906 #= 65024
26 M= 6.071604E-02 S= .9003388 #= 65024
27 M= 5.182702E-03 S= .8759663 #= 65024
28 M=-1.305672E-02 S= .9058192 #= 65024
29 M= 3.046567E-02 S= .8779427 #= 65024
30 M=-6.362266E-02 S= .8666693 #= 65024
31 M=-6.749815E-02 S= .8350653 #= 65024
32 M= 1.076526E-02 S= .8123971 #= 65024
33 M= 8.987451E-02 S= .9130641 #= 65024
34 M=-4.330709E-02 S= .7976447 #= 65024
35 M=-9.862512E-02 S= .8468586 #= 65024
36 M=-1.076526E-04 S= .8006945 #= 65024
37 M= .197404 S= .8668141 #= 65024
38 M= .0428611 S= .8517571 #= 65024
39 M=-4.269193E-02 S= .9046773 #= 65024
40 M= .1357499 S= .9342595 #= 65024
41 M=-.2594119 S= .9603767 #= 65024
42 M= 9.773315E-02 S= .8444525 #= 65024
43 M=-1.028851E-02 S= .8497376 #= 65024
44 M= .0292046 S= .8864924 #= 65024
45 M= .1754429 S= .9380529 #= 65024
46 M=-.1991572 S= .8647073 #= 65024
47 M= .1368264 S= .8723457 #= 65024
48 M=-3.068098E-02 S= .8390067 #= 65024
49 M= 3.195743E-02 S= .8405433 #= 65024
50 M=-.3344304 S= .8444122 #= 65024
51 M= .4294876 S= .9751278 #= 65024
52 M=-.3763841 S= .93503 #= 65024
53 M= .2937377 S= .8953313 #= 65024
54 M=-.1288755 S= .8287175 #= 65024
55 M=-.1224163 S= .8642861 #= 65024
56 M= .081047 S= .864956 #= 65024
57 M= 6.228469E-03 S= .8129649 #= 65024
58 M= 2.193036E-02 S= .9512414 #= 65024
59 M= 5.828617E-02 S= .9078473 #= 65024
```

TOTAL # HOPS : -6536
TOTAL # BITS WHICH HOPPED : 10708
TOTAL # ROWS WHICH HAD A HOPPER: 254
TOTAL # COLS WHICH HAD A HOPPER: 65

Vendor 2
S/N 327

#HOPS	#BITS	HOP	#HOPS	HOP	#HOPS	DURATION	#HOPS
0	0	+ 0	0	- 0	0	0	0
1	2413	+ 1	0	- 1	0	1	16807
2	1886	+ 2	0	- 2	0	2	5168
3	1193	+ 3	15398	- 3	16157	3	3249
4	1026	+ 4	6614	- 4	6806	4	2407
5	686	+ 5	3232	- 5	3151	5	1891
6	603	+ 6	1643	- 6	1649	6	1480
7	416	+ 7	915	- 7	919	7	1118
8	368	+ 8	484	- 8	503	8	966
9	291	+ 9	285	- 9	292	9	800
10	280	+ 10	169	- 10	174	10	682
11	205	+ 11	128	- 11	97	11	605
12	147	+ 12	73	- 12	72	12	495
13	175	+ 13	44	- 13	38	13	411
14	133	+ 14	30	- 14	24	14	417
15	115	+ 15	13	- 15	17	15	352
16	97	+ 16	10	- 16	14	16	297
17	79	+ 17	7	- 17	7	17	271
18	73	+ 18	7	- 18	6	18	444
19	77	+ 19	3	- 19	3	19	354
20	63	+ 20	3	- 20	1	20	281
21	62	+ 21	1	- 21	3	21	216
22	48	+ 22	1	- 22	1	22	217
23	35	+ 23	1	- 23	2	23	193
24	37	+ 24	2	- 24	0	24	168
25	28	+ 25	0	- 25	0	25	135
26	28	+ 26	1	- 26	0	26	135
27	27	+ 27	0	- 27	0	27	314
28	18	+ 28	0	- 28	0	28	205
29	20	+ 29	0	- 29	0	29	153
30	18	+ 30	0	- 30	0	30	145
31	7	+ 31	0	- 31	0	31	106
32	7	+ 32	0	- 32	0	32	92
33	7	+ 33	0	- 33	0	33	73
34	7	+ 34	0	- 34	0	34	82
35	10	+ 35	0	- 35	0	35	85
36	4	+ 36	0	- 36	0	36	249
37	5	+ 37	0	- 37	0	37	150
38	1	+ 38	0	- 38	0	38	133
39	5	+ 39	0	- 39	0	39	96
40	1	+ 40	0	- 40	0	40	90
41	2	+ 41	0	- 41	0	41	73
42	2	+ 42	0	- 42	0	42	66
43	0	+ 43	0	- 43	0	43	56
44	2	+ 44	0	- 44	0	44	54
45	0	+ 45	0	- 45	0	45	203
46	0	+ 46	0	- 46	0	46	146
47	0	+ 47	0	- 47	0	47	99

48	1	+ 48	0	- 48	0	48	77
49	0	+ 49	0	- 49	0	49	66
50	0	+ 50	0	- 50	0	50	61
51	0	+ 51	0	- 51	0	51	58
52	0	+ 52	0	- 52	0	52	36
53	0	+ 53	0	- 53	0	53	40
54	0	+ 54	0	- 54	0	54	224
55	0	+ 55	0	- 55	0	55	28
56	0	+ 56	0	- 56	0	56	8
57	0	+ 57	0	- 57	0	57	5
58	0	+ 58	0	- 58	0	58	2
59	0	+ 59	0	- 59	0	59	0
60	0	+ 60	0	- 60	0	60	0
61	0	+ 61	0	- 61	0	61	0
62	0	+ 62	0	- 62	0	62	0
63	0	+ 63	0	- 63	0	63	0
64	0	+ 64	0	- 64	0	64	0
65	0	+ 65	0	- 65	0	65	0
66	0	+ 66	0	- 66	0	66	0
67	0	+ 67	0	- 67	0	67	0
68	0	+ 68	0	- 68	0	68	0
69	0	+ 69	0	- 69	0	69	0
70	0	+ 70	0	- 70	0	70	0
71	0	+ 71	0	- 71	0	71	0
72	0	+ 72	0	- 72	0	72	0
73	0	+ 73	0	- 73	0	73	0
74	0	+ 74	0	- 74	0	74	0
75	0	+ 75	0	- 75	0	75	0
76	0	+ 76	0	- 76	0	76	0
77	0	+ 77	0	- 77	0	77	0
78	0	+ 78	0	- 78	0	78	0
79	0	+ 79	0	- 79	0	79	0
80	0	+ 80	0	- 80	0	80	0
81	0	+ 81	0	- 81	0	81	0
82	0	+ 82	0	- 82	0	82	0
83	0	+ 83	0	- 83	0	83	0
84	0	+ 84	0	- 84	0	84	0
85	0	+ 85	0	- 85	0	85	0
86	0	+ 86	0	- 86	0	86	0
87	0	+ 87	0	- 87	0	87	0
88	0	+ 88	0	- 88	0	88	0
89	0	+ 89	0	- 89	0	89	0
90	0	+ 90	0	- 90	0	90	0
91	0	+ 91	0	- 91	0	91	0
92	0	+ 92	0	- 92	0	92	0
93	0	+ 93	0	- 93	0	93	0
94	0	+ 94	0	- 94	0	94	0
95	0	+ 95	0	- 95	0	95	0
96	0	+ 96	0	- 96	0	96	0
97	0	+ 97	0	- 97	0	97	0
98	0	+ 98	0	- 98	0	98	0
99	0	+ 99	0	- 99	0	99	0
100	0	+ 100	0	- 100	0	100	0
101	0	+ 101	0	- 101	0	101	0

H FILES 2 TO 60 INDIV AND CUM M,S OF #H VS H Vendor 2
+ BINNED DIFFERENCE MAGNITUDES (EXCLUDING PUMPED ROWS) S/N 327

0:	1396391	824488	246482	75564	31670	14856	7640	4145	2258	1312
10:	770	432	256	161	85	44	40	22	14	6
20:	3	6	1	4	0	0	0	0	0	0
30:	0	0	0	0	0	0	0	0	0	0
40:	0	0	0	0	0	0	0	0	0	0
50:	0	0	0	0	0	0	0	0	0	0
60:	0	0	0	0	0	0	0	0	0	0
70:	0	0	0	0	0	0	0	0	0	0
80:	0	0	0	0	0	0	0	0	0	0
90:	0	0	0	0	0	0	0	0	0	0
100:	0	0								

- BINNED DIFFERENCE MAGNITUDES (EXCLUDING R0 AND R128)

0:		237408	71695	30809	14737	7568	4126	2230	1258	778
10:	512	243	148	84	60	34	18	14	9	7
20:	2	1	1	2	0	2	0	0	0	0
30:	0	0	0	0	0	0	0	0	0	0
40:	0	0	0	0	0	0	0	0	0	0
50:	0	0	0	0	0	0	0	0	0	0
60:	0	0	0	0	0	0	0	0	0	0
70:	0	0	0	0	0	0	0	0	0	0
80:	0	0	0	0	0	0	0	0	0	0
90:	0	0	0	0	0	0	0	0	0	0
100:	0									

0 M= 1.970589E-04 S= 1.500641 #= 3836416
2 M= 6.022392E-02 S= 1.507499 #= 65024
3 M=-.4309332 S= 1.473739 #= 65024
4 M= 4.003137E-02 S= 1.524514 #= 65024
5 M=-8.370756E-02 S= 1.549492 #= 65024
6 M= 4.439899E-02 S= 1.504019 #= 65024
7 M=-5.536417E-03 S= 1.523249 #= 65024
8 M= .142655 S= 1.618891 #= 65024
9 M=-2.276083E-02 S= 1.593235 #= 65024
10 M=-5.161171E-02 S= 1.453972 #= 65024
11 M= 1.800874E-02 S= 1.425758 #= 65024
12 M=-3.950849E-02 S= 1.44908 #= 65024
13 M=-.3776452 S= 1.438904 #= 65024
14 M= .3253875 S= 1.442368 #= 65024
15 M=-2.312992E-02 S= 1.461243 #= 65024
16 M=-.101624 S= 1.477411 #= 65024
17 M= .6848087 S= 1.420611 #= 65024
18 M=-.3002276 S= 1.426368 #= 65024
19 M=-.0330032 S= 1.495777 #= 65024
20 M= .1694913 S= 1.482993 #= 65024
21 M= .1848548 S= 1.738472 #= 65024
22 M= .1186639 S= 1.53887 #= 65024
23 M=-.1548813 S= 1.544998 #= 65024
24 M=-1.162648E-02 S= 1.55088 #= 65024

```
25 M=-3.460261E-02 S= 1.507244 #= 65024
26 M= 9.845596E-02 S= 1.482509 #= 65024
27 M=-.1830555 S= 1.454719 #= 65024
28 M= .1091136 S= 1.498559 #= 65024
29 M= 4.276882E-02 S= 1.512834 #= 65024
30 M=-.155112 S= 1.489267 #= 65024
31 M=-5.820928E-02 S= 1.488922 #= 65024
32 M=-.0572404 S= 1.438596 #= 65024
33 M= .1170183 S= 1.384711 #= 65024
34 M= 3.489481E-02 S= 1.42268 #= 65024
35 M=-4.827448E-02 S= 1.545328 #= 65024
36 M=-2.512918E-02 S= 1.490936 #= 65024
37 M= .1677688 S= 1.439044 #= 65024
38 M= .1275837 S= 1.519648 #= 65024
39 M=-.1662463 S= 1.484475 #= 65024
40 M= 8.198512E-02 S= 1.524601 #= 65024
41 M=-8.103162E-02 S= 1.61 #= 65024
42 M= 2.754368E-02 S= 1.407814 #= 65024
43 M=-.1142655 S= 1.401186 #= 65024
44 M= .1227085 S= 1.426341 #= 65024
45 M= .2052934 S= 1.489344 #= 65024
46 M=-8.443037E-02 S= 1.505816 #= 65024
47 M= .1839782 S= 1.461658 #= 65024
48 M= 5.305733E-03 S= 1.440019 #= 65024
49 M=-.1779035 S= 1.525549 #= 65024
50 M=-.1895608 S= 1.422722 #= 65024
51 M= .2141978 S= 1.473012 #= 65024
52 M=-.1721211 S= 1.433534 #= 65024
53 M= 7.308071E-02 S= 1.402555 #= 65024
54 M=-.216966 S= 1.447581 #= 65024
55 M= 5.071973E-02 S= 1.485737 #= 65024
56 M=-.1252461 S= 1.421384 #= 65024
57 M= .163232 S= 1.442485 #= 65024
58 M= 8.602978E-02 S= 1.662534 #= 65024
59 M=-1.362574E-02 S= 1.616015 #= 65024
```

TOTAL # HOPS : -6536
TOTAL # BITS WHICH HOPPED : 12192
TOTAL # ROWS WHICH HAD A HOPPER: 254
TOTAL # COLS WHICH HAD A HOPPER: 80

Vendor 2
S/N 328

#HOPS	#BITS	HOP	#HOPS	HOP	#HOPS	DURATION	#HOPS
0	0	+ 0	0	- 0	0	0	0
1	3211	+ 1	0	- 1	0	1	15932
2	2260	+ 2	0	- 2	0	2	4860
3	1485	+ 3	17299	- 3	17600	3	3291
4	1007	+ 4	6746	- 4	6729	4	2393
5	767	+ 5	2761	- 5	2718	5	1743
6	595	+ 6	1273	- 6	1329	6	1407
7	484	+ 7	618	- 7	637	7	1134
8	393	+ 8	335	- 8	289	8	1000
9	312	+ 9	161	- 9	160	9	812
10	270	+ 10	93	- 10	83	10	655
11	221	+ 11	42	- 11	47	11	570
12	180	+ 12	27	- 12	26	12	526
13	137	+ 13	6	- 13	2	13	482
14	118	+ 14	5	- 14	6	14	413
15	115	+ 15	3	- 15	1	15	390
16	83	+ 16	1	- 16	2	16	314
17	71	+ 17	0	- 17	0	17	297
18	71	+ 18	1	- 18	0	18	450
19	66	+ 19	0	- 19	0	19	319
20	59	+ 20	0	- 20	0	20	279
21	48	+ 21	0	- 21	0	21	251
22	33	+ 22	0	- 22	0	22	196
23	33	+ 23	0	- 23	0	23	201
24	31	+ 24	0	- 24	0	24	174
25	24	+ 25	0	- 25	0	25	129
26	22	+ 26	0	- 26	0	26	152
27	24	+ 27	0	- 27	0	27	258
28	12	+ 28	0	- 28	0	28	207
29	11	+ 29	0	- 29	0	29	165
30	13	+ 30	0	- 30	0	30	139
31	8	+ 31	0	- 31	0	31	126
32	3	+ 32	0	- 32	0	32	99
33	6	+ 33	0	- 33	0	33	118
34	4	+ 34	0	- 34	0	34	75
35	5	+ 35	0	- 35	0	35	76
36	2	+ 36	0	- 36	0	36	204
37	2	+ 37	0	- 37	0	37	158
38	1	+ 38	0	- 38	0	38	114
39	1	+ 39	0	- 39	0	39	104
40	2	+ 40	0	- 40	0	40	91
41	0	+ 41	0	- 41	0	41	81
42	0	+ 42	0	- 42	0	42	58
43	1	+ 43	0	- 43	0	43	39
44	1	+ 44	0	- 44	0	44	49
45	0	+ 45	0	- 45	0	45	191
46	0	+ 46	0	- 46	0	46	115
47	0	+ 47	0	- 47	0	47	97

48	0	+ 48	0	- 48	0	48	79
49	0	+ 49	0	- 49	0	49	64
50	0	+ 50	0	- 50	0	50	54
51	0	+ 51	0	- 51	0	51	49
52	0	+ 52	0	- 52	0	52	49
53	0	+ 53	0	- 53	0	53	43
54	0	+ 54	0	- 54	0	54	204
55	0	+ 55	0	- 55	0	55	29
56	0	+ 56	0	- 56	0	56	15
57	0	+ 57	0	- 57	0	57	8
58	0	+ 58	0	- 58	0	58	1
59	0	+ 59	0	- 59	0	59	0
60	0	+ 60	0	- 60	0	60	0
61	0	+ 61	0	- 61	0	61	0
62	0	+ 62	0	- 62	0	62	0
63	0	+ 63	0	- 63	0	63	0
64	0	+ 64	0	- 64	0	64	0
65	0	+ 65	0	- 65	0	65	0
66	0	+ 66	0	- 66	0	66	0
67	0	+ 67	0	- 67	0	67	0
68	0	+ 68	0	- 68	0	68	0
69	0	+ 69	0	- 69	0	69	0
70	0	+ 70	0	- 70	0	70	-
71	0	+ 71	0	- 71	0	71	0
72	0	+ 72	0	- 72	0	72	0
73	0	+ 73	0	- 73	0	73	0
74	0	+ 74	0	- 74	0	74	0
75	0	+ 75	0	- 75	0	75	0
76	0	+ 76	0	- 76	0	76	0
77	0	+ 77	0	- 77	0	77	0
78	0	+ 78	0	- 78	0	78	0
79	0	+ 79	0	- 79	0	79	0
80	0	+ 80	0	- 80	0	80	0
81	0	+ 81	0	- 81	0	81	0
82	0	+ 82	0	- 82	0	82	0
83	0	+ 83	0	- 83	0	83	0
84	0	+ 84	0	- 84	0	84	0
85	0	+ 85	0	- 85	0	85	0
86	0	+ 86	0	- 86	0	86	0
87	0	+ 87	0	- 87	0	87	0
88	0	+ 88	0	- 88	0	88	0
89	0	+ 89	0	- 89	0	89	0
90	0	+ 90	0	- 90	0	90	0
91	0	+ 91	0	- 91	0	91	0
92	0	+ 92	0	- 92	0	92	0
93	0	+ 93	0	- 93	0	93	0
94	0	+ 94	0	- 94	0	94	0
95	0	+ 95	0	- 95	0	95	0
96	0	+ 96	0	- 96	0	96	0
97	0	+ 97	0	- 97	0	97	0
98	0	+ 98	0	- 98	0	98	0
99	0	+ 99	0	- 99	0	99	0
100	0	+ 100	0	- 100	0	100	0
101	0	+ 101	0	- 101	0	101	0

H FILES 2 TO 60 INDIV AND CUM M,S OF #H VS H Vendor 2
+ BINNED DIFFERENCE MAGNITUDES (EXCLUDING PUMPED ROWS) S/N 328

0:	1561662	804803	210741	65519	24964	10473	4679	2259	1064	531
10:	265	145	82	33	24	6	5	2	0	0
20:	0	0	0	0	0	0	0	0	0	0
30:	0	0	0	0	0	0	0	0	0	0
40:	0	0	0	0	0	0	0	0	0	0
50:	0	(	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0	0	0	0
80:	0	0	0	0	0	0	0	0	0	0
90:	0	0	0	0	0	0	0	0	0	0
100:	0	0								

- BINNED DIFFERENCE MAGNITUDES (EXCLUDING R0 AND R128)

0:	203611	63832	24656	10196	4677	2164	1047	498	305
10:	143	81	38	17	14	9	2	2	0	0
20:	0	0	0	0	0	0	0	0	0	0
30:	0	0	0	0	0	0	0	0	0	0
40:	0	0	0	0	0	0	0	0	0	0
50:	0	0	0	0	0	0	0	0	0	0
60:	0	0	0	0	0	0	0	0	0	0
70:	0	0	0	0	0	0	0	0	0	0
80:	0	0	0	0	0	0	0	0	0	0
90:	0	0	0	0	0	0	0	0	0	0
100:	0									

0 M=-2.754915E-03 S= 1.320742 #= 3836416
2 M= 4.590613E-02 S= 1.380469 #= 65024
3 M=-.3172675 S= 1.315558 #= 65024
4 M= 5.688669E-02 S= 1.363986 #= 65024
5 M= 2.414493E-03 S= 1.381731 #= 65024
6 M= 1.078064E-02 S= 1.307247 #= 65024
7 M=-.1472841 S= 1.345161 #= 65024
8 M= 9.175074E-02 S= 1.449946 #= 65024
9 M= 2.491388E-02 S= 1.404018 #= 65024
10 M=-4.850517E-02 S= 1.28789 #= 65024
11 M=-.0167169 S= 1.291275 #= 65024
12 M=-2.935839E-02 S= 1.296174 #= 65024
13 M=-.1506674 S= 1.314541 #= 65024
14 M= .1331816 S= 1.274974 #= 65024
15 M=-9.934793E-02 S= 1.2816 #= 65024
16 M=-3.975455E-02 S= 1.31518 #= 65024
17 M= .5673597 S= 1.279275 #= 65024
18 M=-.2028174 S= 1.263795 #= 65024
19 M= 3.143455E-02 S= 1.316638 #= 65024
20 M= 4.925874E-02 S= 1.295594 #= 65024
21 M= .1102362 S= 1.564636 #= 65024
22 M= 9.156619E-02 S= 1.370837 #= 65024
23 M=-.1062223 S= 1.38347 #= 65024
24 M=-2.531373E-02 S= 1.349213 #= 65024

```
25 M=-9.187377E-02 S= 1.298179 #= 65024
26 M= .110267 S= 1.289061 #= 65024
27 M=-.1683379 S= 1.285537 #= 65024
28 M= 9.078187E-02 S= 1.293217 #= 65024
29 M= 7.586429E-02 S= 1.316247 #= 65024
30 M=-.1425935 S= 1.295158 #= 65024
31 M=-9.342704E-02 S= 1.312155 #= 65024
32 M= 2.921998E-03 S= 1.254783 #= 65024
33 M= .1093596 S= 1.255126 #= 65024
34 M= 4.144624E-02 S= 1.247838 #= 65024
35 M=-.1279835 S= 1.328263 #= 65024
36 M=-.0358483 S= 1.288895 #= 65024
37 M= .128045 S= 1.27305 #= 65024
38 M= .157388 S= 1.32985 #= 65024
39 M=-.1718289 S= 1.299008 #= 65024
40 M= .1213706 S= 1.347136 #= 65024
41 M=-4.890502E-02 S= 1.436775 #= 65024
42 M= 4.406065E-02 S= 1.232669 #= 65024
43 M=-.0508889 S= 1.228281 #= 65024
44 M= 3.311085E-02 S= 1.270703 #= 65024
45 M= .1825941 S= 1.301822 #= 65024
46 M=-8.626046E-02 S= 1.318281 #= 65024
47 M= .1288447 S= 1.273561 #= 65024
48 M=-2.629798E-03 S= 1.239511 #= 65024
49 M=-.1134812 S= 1.307613 #= 65024
50 M=-.2272853 S= 1.236588 #= 65024
51 M= .2456631 S= 1.286807 #= 65024
52 M=-.1767194 S= 1.269265 #= 65024
53 M= .0530112 S= 1.238367 #= 65024
54 M=-.2374662 S= 1.285794 #= 65024
55 M= 2.529835E-02 S= 1.30647 #= 65024
56 M=-.1108821 S= 1.241681 #= 65024
57 M= 8.659879E-02 S= 1.247358 #= 65024
58 M= 9.102793E-02 S= 1.466523 #= 65024
59 M= 7.449557E-02 S= 1.403676 #= 65024
```

Appendix E

Typical Views During Die Delayering

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1.0 Introduction

Delayering techniques, obtained from the vendors, were used to reveal layers for defect inspection. Because of the die construction (double layer, single level polysilicon), parts of both polysilicon layers were removed at some steps. Unfortunately, the vendors do not have a technique to selectively remove a single polysilicon layer. Layer removal was also hampered by wide variation of etch rates part-to-part and at different regions of the die on the same part. For this reason, trial etching of sample parts did not provide guidance for refining the etching of the physical analysis parts. Some layers were therefore not as "clean" for inspection as we had hoped.

The die of one part from each manufacturer was delayered and 10 bit locations (five with the lowest refresh times and five with the highest refresh times) were examined optically for defects at each step at magnifications of 500X to 1000X. The following table identifies the inspected bits.

Vendor	S/N	Bit	Row	Column	Initial tref (sec)	Comments
1	138	1	238	154	2.99	Low
1	138	2	54	110	3.79	Low
1	138	3	112	0	8.09	Low
1	138	4	92	0	9.59	Low
1	138	5	118	0	9.59	Low
1	138	6	33	209	30.59	High
1	138	7	72	114	32.09	High
1	138	8	84	217	32.09	High
1	138	9	68	77	33.59	High
1	138	10	160	122	32.09	High
2	338	1	140	224	N/A	Failed bit
2	338	2	15	0	3.06	High
2	338	3	1	38	0.06	Low
2	338	4	1	167	0.06	Low
2	338	5	210	255	4.06	High
2	338	6	252	177	0.15	Low
2	338	7	252	181	0.15	Low
2	338	8	255	138	2.81	High
2	338	9	128	132	3.06	High
2	338	10	191	1	2.56	High

We inspected each layer for defects and anomalies and saw none. The following cross-reference correlates the layers with photos of typical memory bits.

Vendor 1 layers:	Figures (Bit number shown)
Passivation	E-1, E-2 (Bit 10)
Metal	E-3, E-4 (Bit 3)
Borophosphosilicate glass (BPSG)	E-5 (Bit 10), E-6 (Bit 3)
Polysilicon 2	E-7, E-8 (Bit 3)
Passivation	
Polysilicon 1	E-7, E-8 (Bit 3)
Memory/gate dielectric	E-9, E-10 (Bit 3)
Vendor 2 layers:	
Passivation	E-11, E-12 (Bit 1)
Metal	E-13, E-14 (Bit 3)
Chemical vapor deposition (CVD) oxide	E-15, E-16 (Bit 3)
Polysilicon 2	E-17, E-18 (Bit 3)
CVD oxide	E-19, E-20 (Bit 3)
Polysilicon 1	E-17, E-18, E-21, E-22 (Bit 3)
Memory/gate dielectric	E-19, E-20, E-23, E-24 (Bit 3)

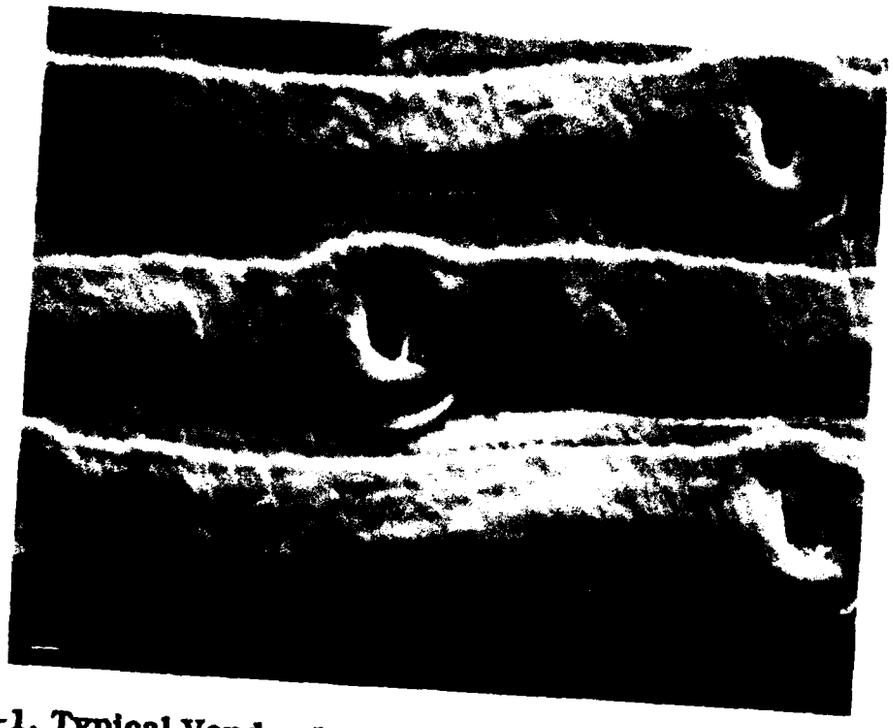


Figure E-1. Typical Vendor 1 Memory Cell at Top Passivation Layer (SEM 5000X)

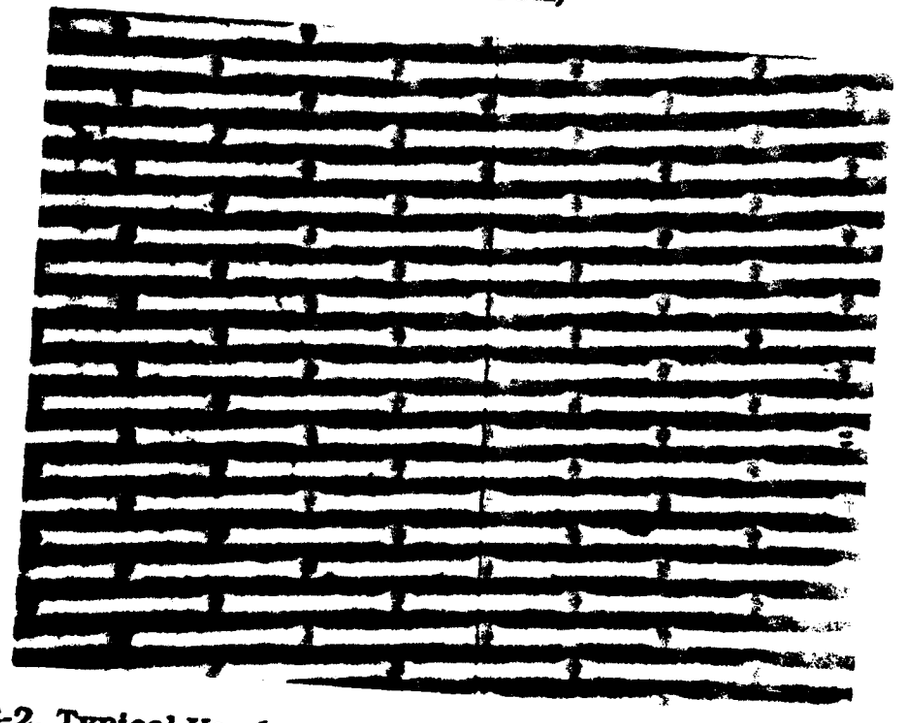


Figure E-2. Typical Vendor 1 Memory Cell at Top Passivation Layer (Optical 900X)

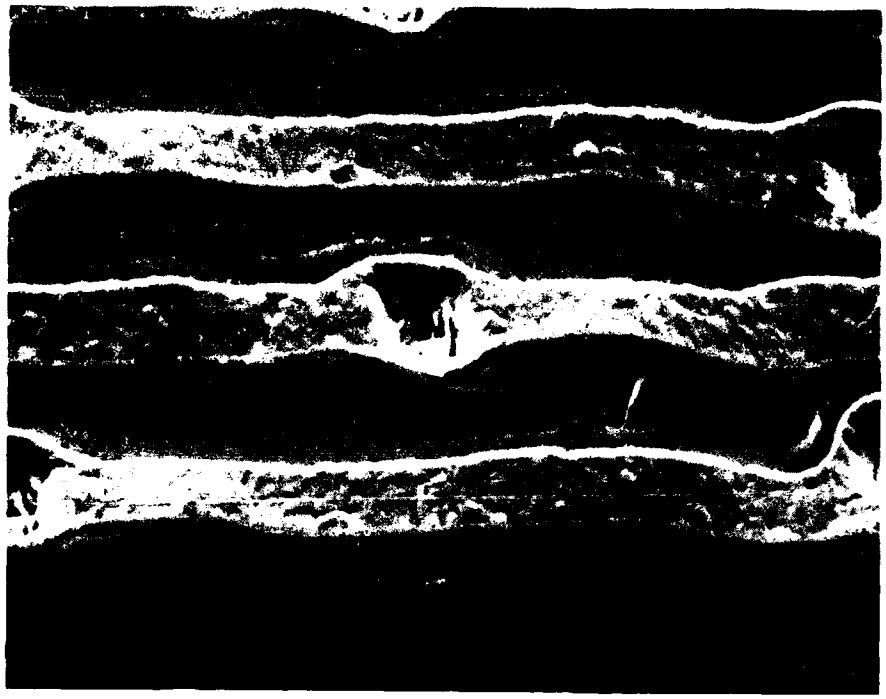


Figure E-3. Typical Vendor 1 Memory Cell at Metallization Layer (SEM 5000X)

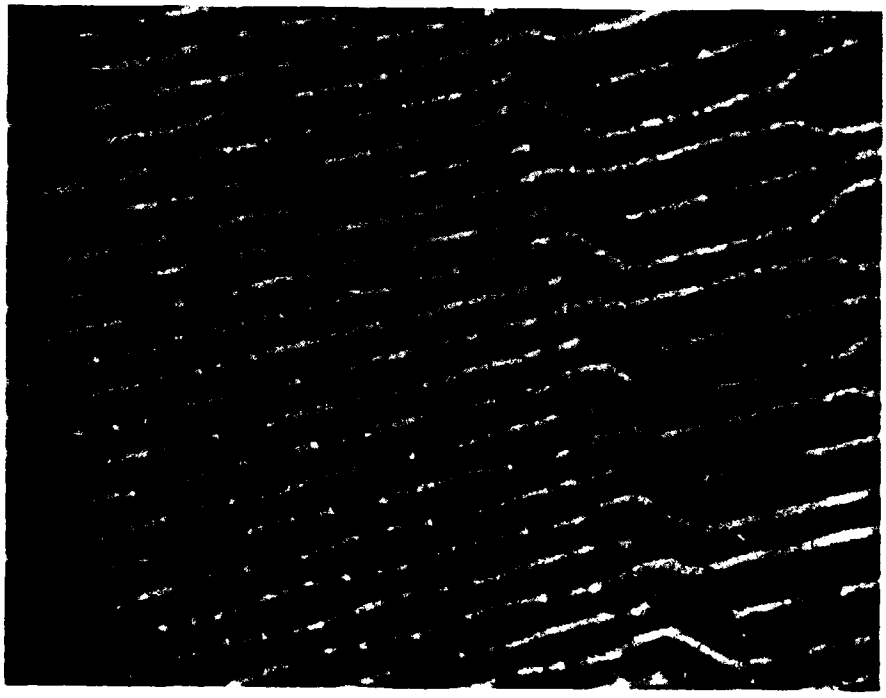


Figure E-4. Typical Vendor 1 Memory Cell at Metallization Layer (Optical 900X)

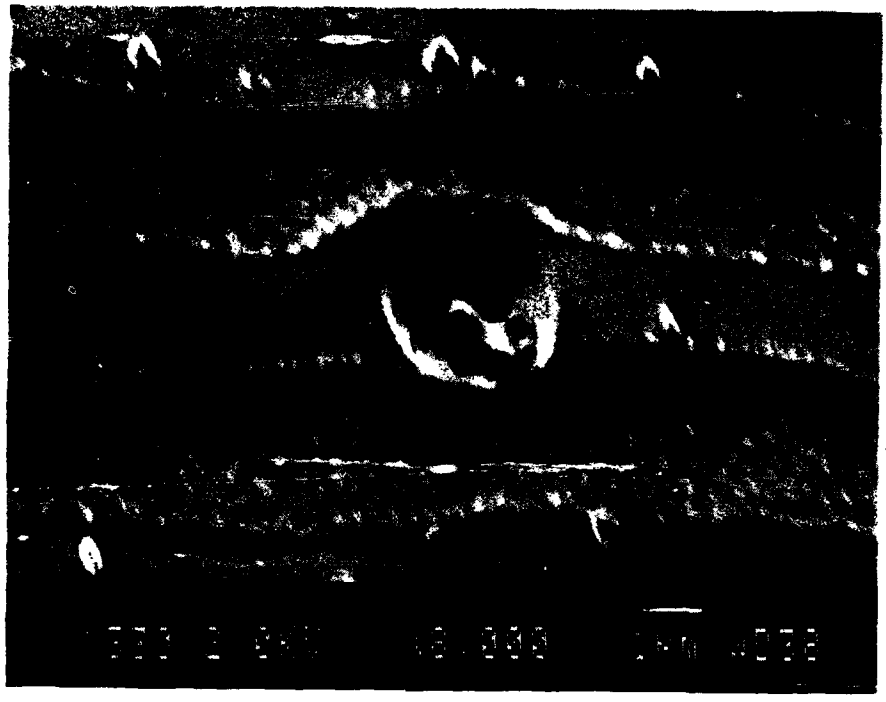


Figure E-5. Typical Vendor 1 Memory Cell at BPSG Layer (SEM 8000X)

Figure E-6. Typical Vendor 1 Memory Cell at BPSG Layer (Optical 900X)

Figure E-7. Typical Vendor 1 Memory Cell at Polysilicon Layers (SEM 5000X)

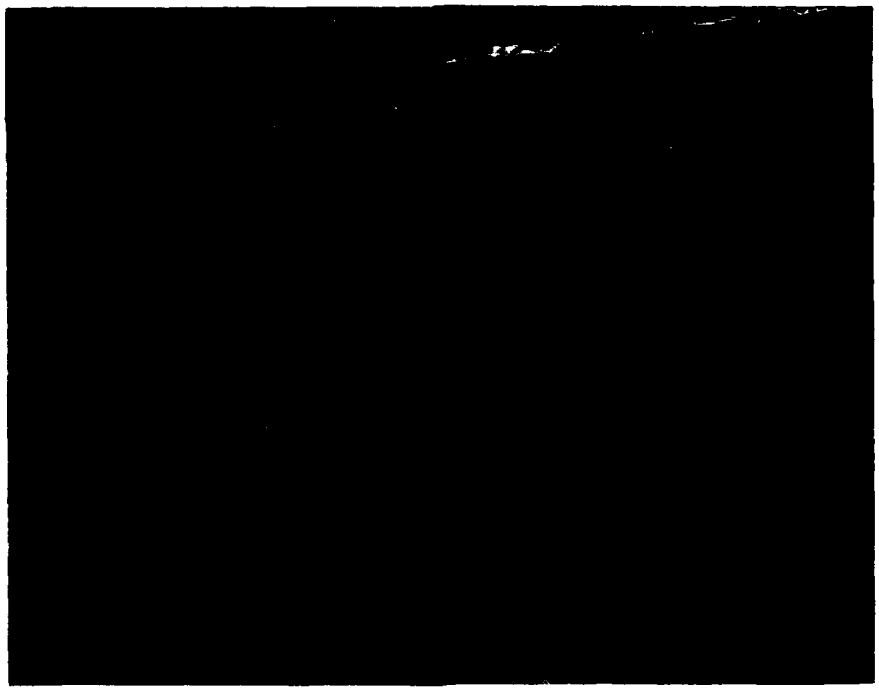
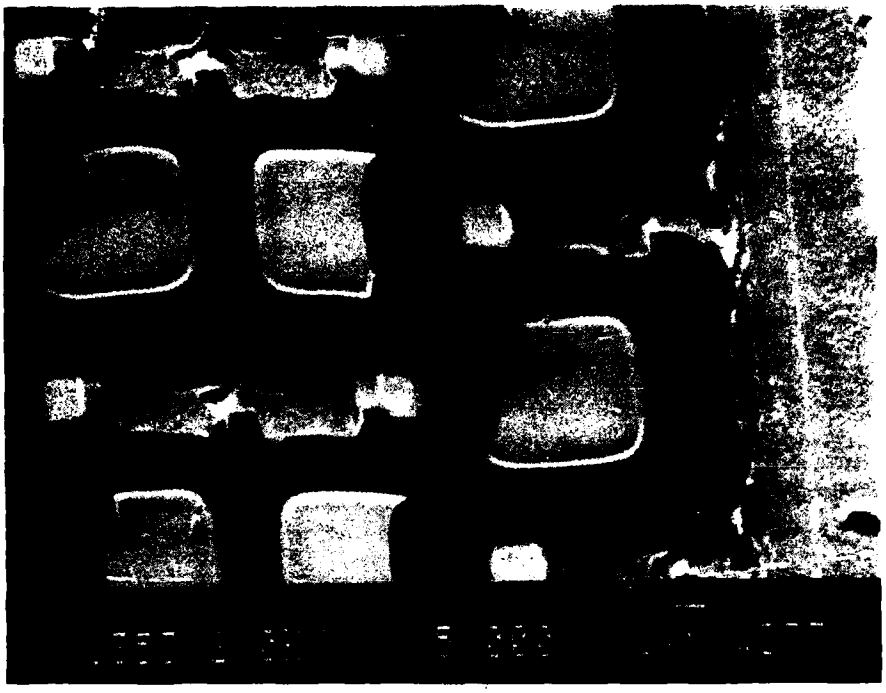


Figure E-8. Typical Vendor 1 Memory Cell at Polysilicon Layers (Optical 900X)



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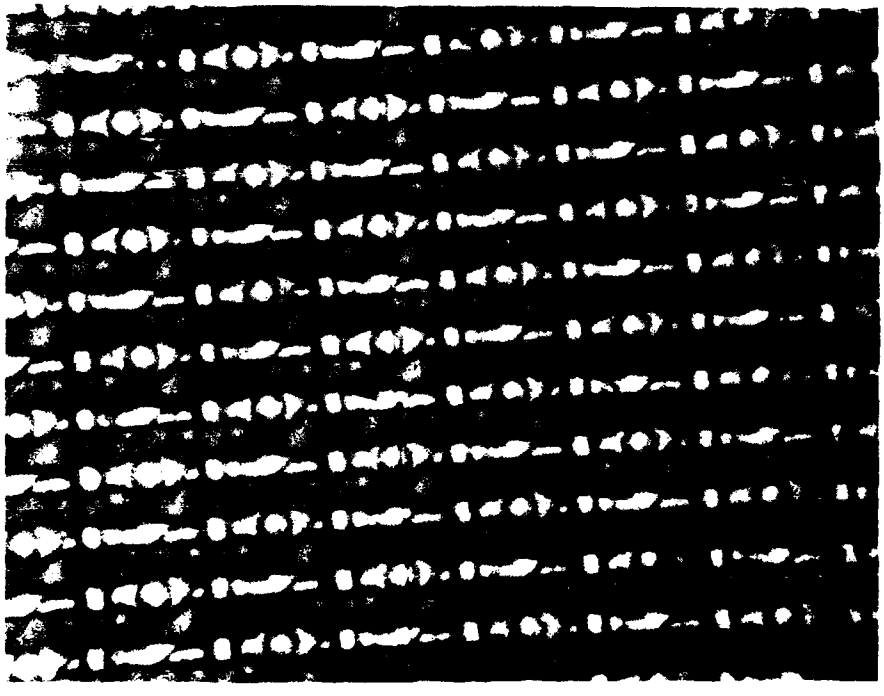

Figure E-12. Typical Vendor 2 Memory Cell at Top Passivation Layer (Optical 900X)

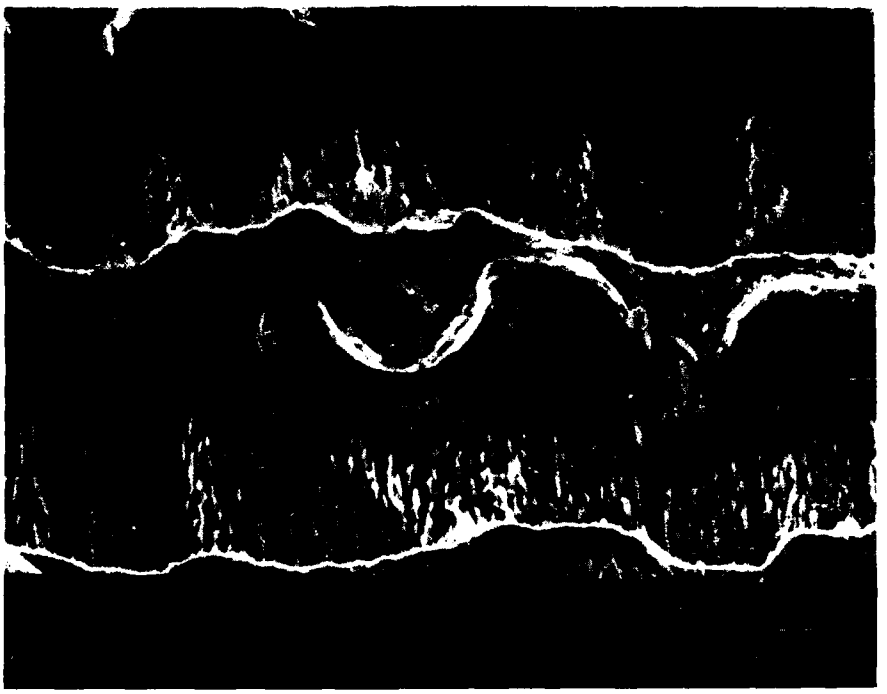

Figure E-13. Typical Vendor 2 Memory Cell at Metallization Layer (SEM 5000X)

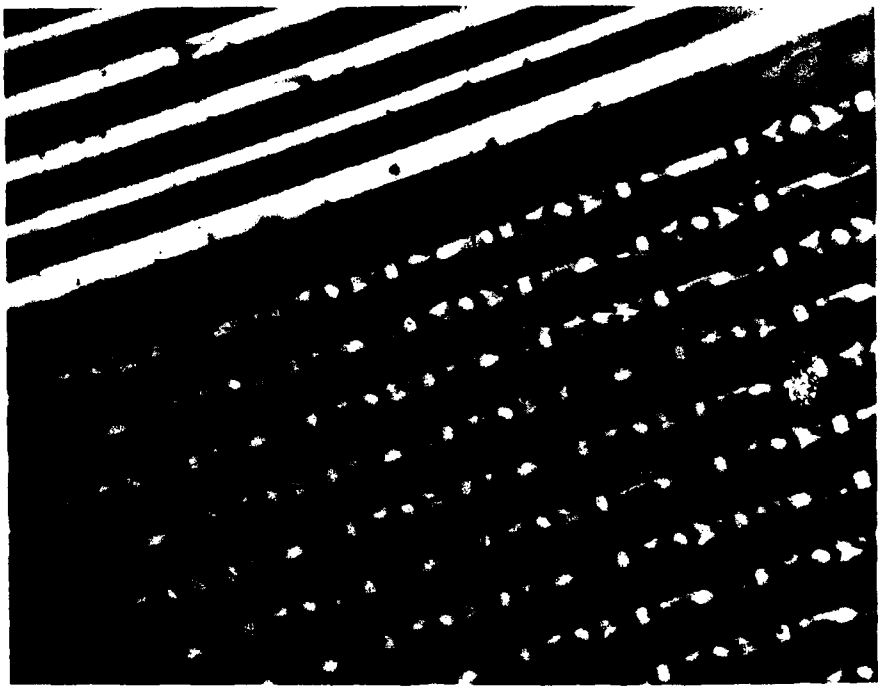

Figure E-14. Typical Vendor 2 Memory Cell at Metallization Layer (Optical 900X)

Figure E-15. Typical Vendor 2 Memory Cell at CVD Layer (SEM 5000X)

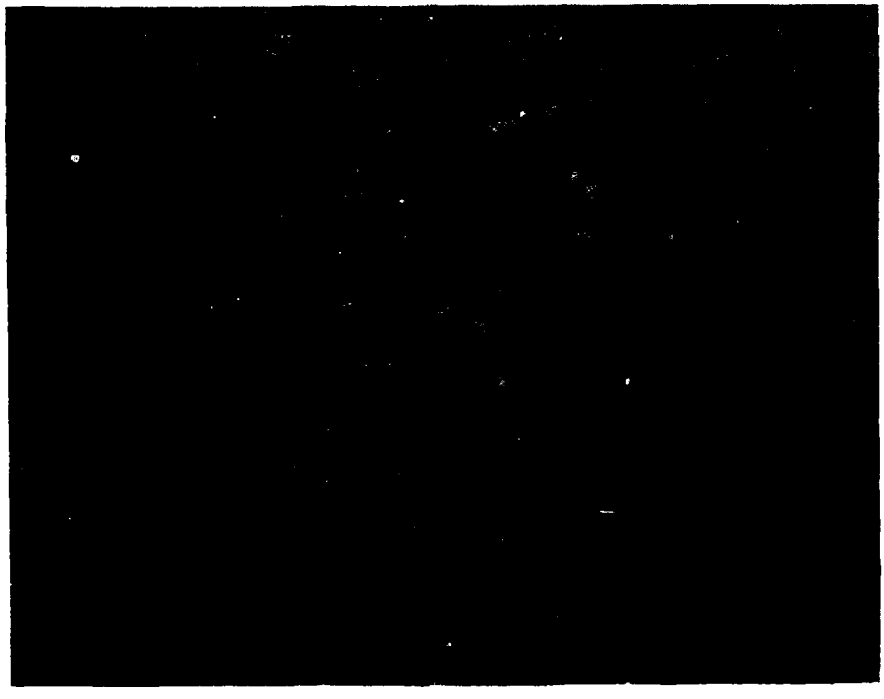

Figure E-16. Typical Vendor 2 Memory Cell at CVD Layer (Optical 900X)

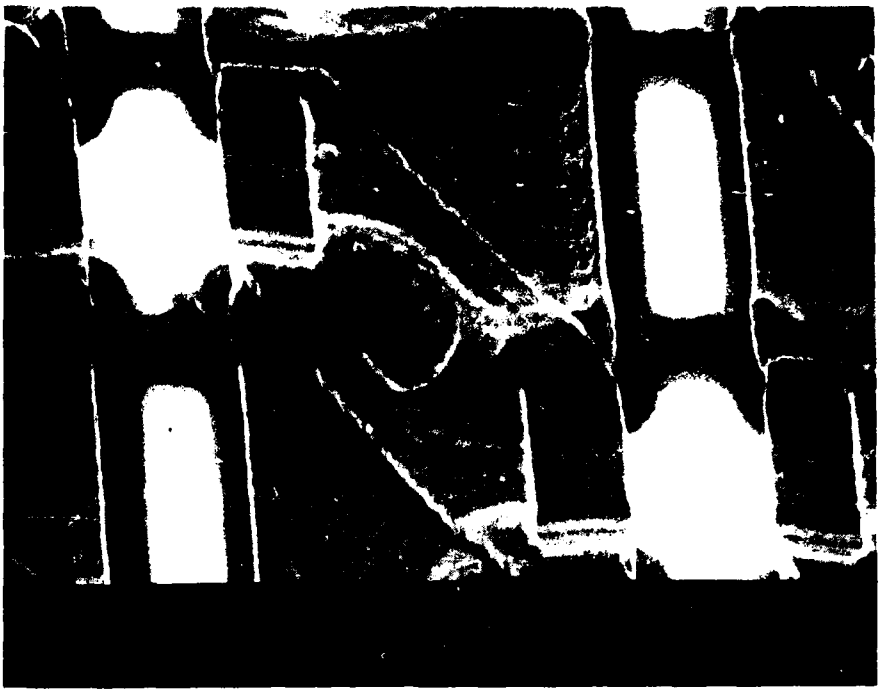

Figure E-17. Typical Vendor 2 Memory Cell at Polysilicon Layers (SEM 4500X)

Figure E-18. Typical Vendor 2 Memory Cell at Polysilicon Layers (Optical 900X)

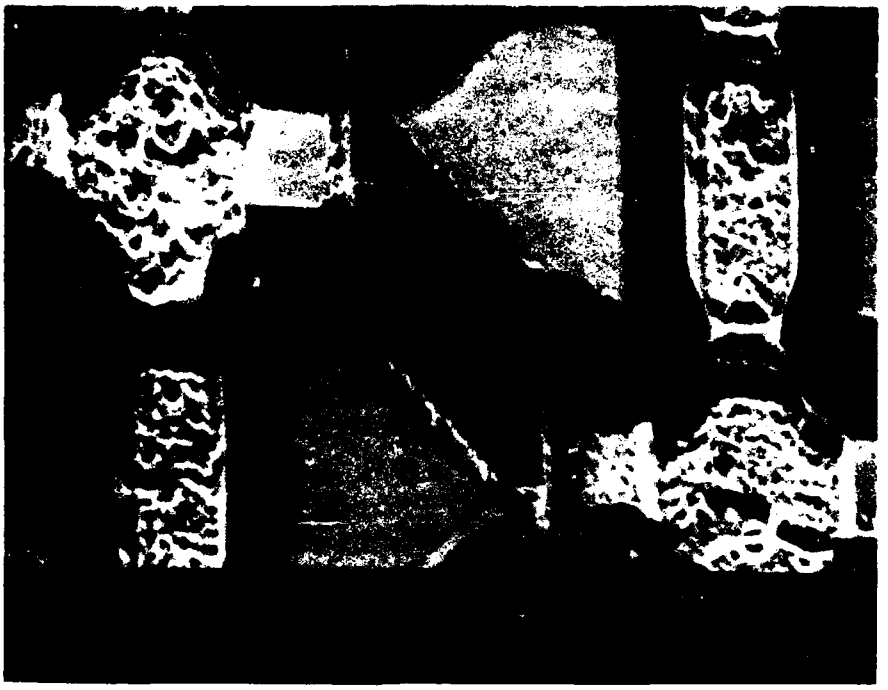

Figure E-19. Typical Vendor 2 Memory Cell at Memory/Gate Dielectric Layer 1 (SEM 5000X)

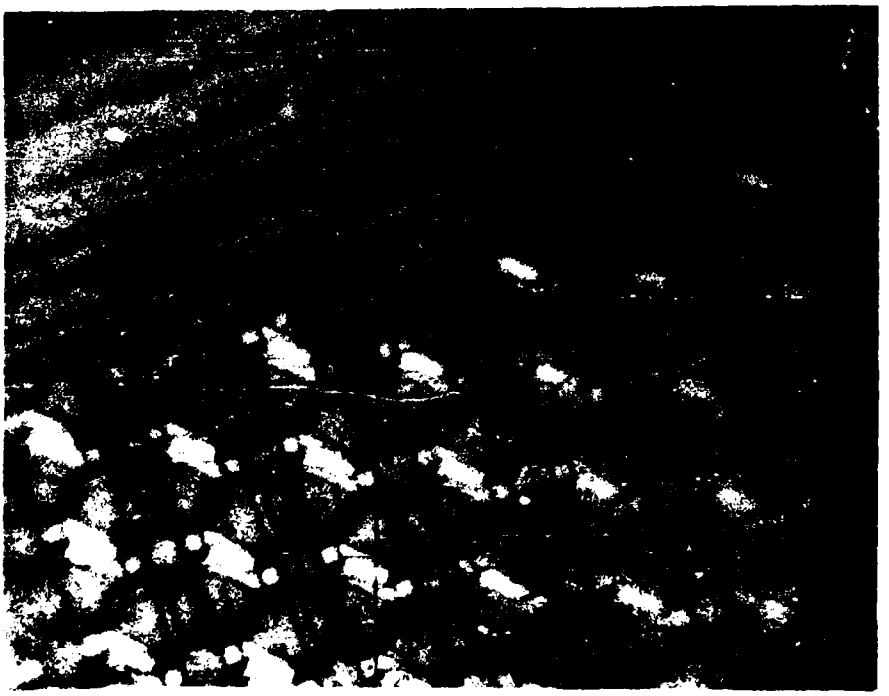

Figure E-20. Typical Vendor 2 Memory Cell at Memory/Gate Dielectric Layer 1 (Optical 900X)

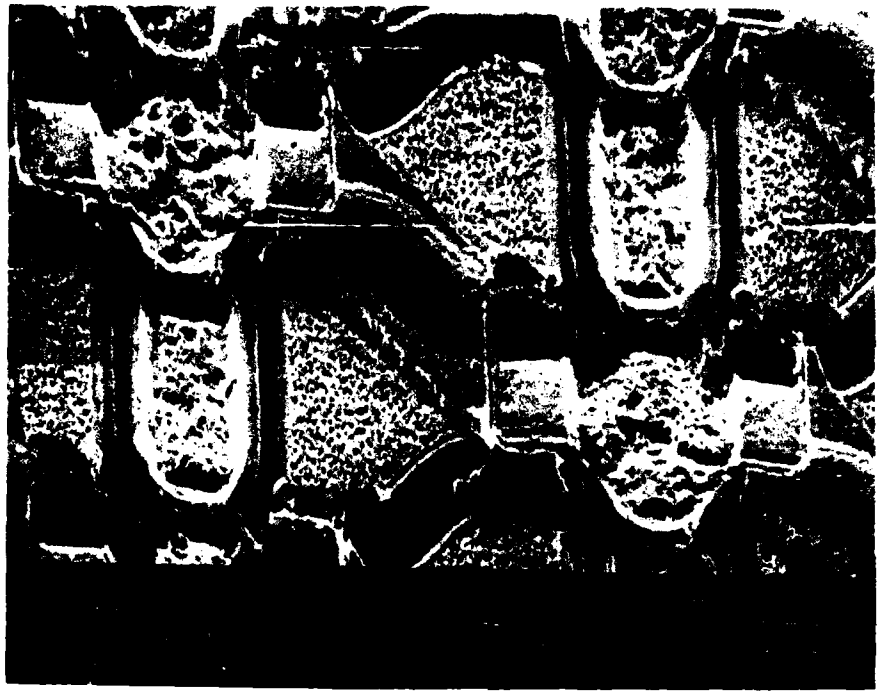

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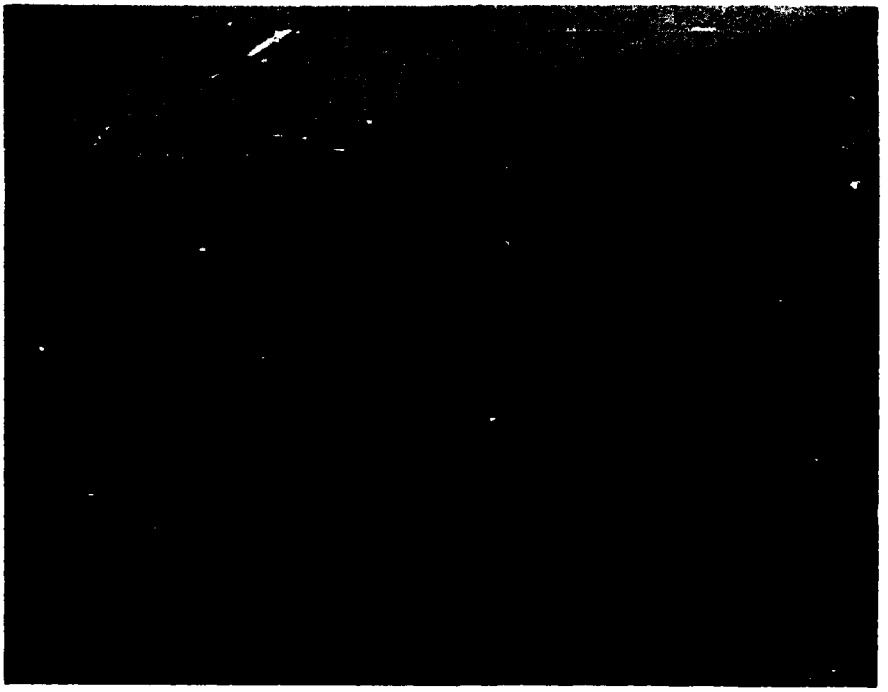
Figure E-22. Typical Vendor 2 Memory Cell at Interlevel CVD Layer (Optical 900X)

Figure E-23. Typical Vendor 2 Memory Cell at Memory Dielectric Layer 2 (SEM 5000X)



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Appendix F

Summary of Refresh Times Measured with Tektronix S-3270

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1.0 Introduction

Summarizing data is not always a straightforward task. The refresh data measured during the life tests is summarized here using mean, sigma, mean delta, and sigma delta. Mean is defined as:

$$m = \frac{1}{n}\Sigma X_i$$

and sigma is defined as:

$$s = SQRT\left[\frac{1}{n-1}\left[\Sigma X_i^2 - \frac{1}{n}(\Sigma X_i)^2\right]\right]$$

Deltas are with respect to initial values.

Figures F-1 through F-12 summarize the refresh times measured at three points during life tests. This analysis shows a variation of the means and sigmas, however no consistent trend was observed. Mean and sigma of the 1000 random and 1000 worst-case bits as well as the delta of these values from initial results are presented.

Figures F-13 through F-20 show typical scatter plots of individual bit refresh times and demonstrate that Vendor 1 exhibited more instability than Vendor 2.

Figures F-21 through F-24 show typical cumulative plots of raw refresh data for both random and worst-case refresh bits for both vendors.

The random bit samples should look like a normal distribution, but the worst-case bit samples should look like a low-tail truncated normal distribution. Therefore, the calculated mean and sigma for the random bit samples correspond to the entire population of bits in the part. However, the mean and sigma calculations used for the worst-case bits do not account for a truncated distribution and so are not descriptive of the entire population of bits.

Vendor 1 Refresh times (seconds) Measured at Vcc=5.5 volts

1000 Random bits

		Mean			Sigma			Mean delta		Sigma delta	
Cell	S/N	0 hrs	160 hrs	4000 hrs	0 hrs	160 hrs	4000 hrs	0 to 160	0 to 4000	0 to 160	0 to 4000
1	130	27.6800	22.3400	23.3100	3.2930	2.5910	3.1960	-5.3400	-4.3700	-0.7020	-0.0970
1	131	25.8900	17.4700	12.1400	3.3260	5.2250	6.6210	-8.4200	-13.7500	1.8990	3.2950
1	132	24.7100	21.7700	24.7400	2.8890	2.4860	2.9250	-2.9400	0.0300	-0.4030	0.0360
1	133	24.8700	25.8300	22.8600	2.8630	3.1000	2.6750	0.9600	-2.0100	0.2370	-0.1880
1	134	24.9400	22.3900	22.7100	2.9290	2.5610	2.6470	-2.5500	-2.2300	-0.3680	-0.2820
1	135	24.8400	21.3300	22.4900	2.6050	2.2160	2.3800	-3.5100	-2.3500	-0.3890	-0.2250
1	137	26.0400	22.0300	23.3300	3.0950	2.5330	2.8440	-4.0100	-2.7100	-0.5620	-0.2510
1	139	25.1800	21.8600	23.5900	2.8670	2.4080	2.7220	-3.3200	-1.5900	-0.4590	-0.1450
1	140	23.8900	21.9100	21.8200	2.5510	2.2940	2.3590	-1.9800	-2.0700	-0.2570	-0.1920
1	141	23.1600	22.3600	21.9200	2.5170	2.4110	2.4310	-0.8000	-1.2400	-0.1060	-0.0860
1	142	23.7000	22.5000	22.6600	2.7760	2.6160	2.7050	-1.2000	-1.0400	-0.1600	-0.0710
1	143	25.0700	22.8600	25.1700	2.7750	2.4710	2.8600	-2.2100	0.1000	-0.3040	0.0850
1	144	24.1600	22.2700	27.2300	2.5290	2.2930	2.9660	-1.8900	3.0700	-0.2360	0.4370
1	145	27.2900	22.6000	27.8100	3.1300	2.5520	3.2280	-4.6900	0.5200	-0.5780	0.0980
1	146	25.3000	22.3000	26.5500	2.9250	2.5200	3.2530	-3.0000	1.2500	-0.4050	0.3280
1	147	24.8900	23.2500	24.7900	2.7590	2.5420	2.8290	-1.6400	-0.1000	-0.2170	0.0700
1	148	23.0200	22.2000	21.9100	2.4690	2.3710	2.3680	-0.8200	-1.1100	-0.0980	-0.0810
1	149	24.6600	23.2400	27.3200	2.7230	2.5250	3.1340	-1.4200	2.6600	-0.1980	0.4110
1	150	23.4700	22.6400	21.5000	2.6180	2.5350	2.3810	-0.8300	-1.9700	-0.0830	-0.2370
1	151	26.6400	23.6100	23.9400	3.2120	2.8280	2.9760	-3.0300	-2.7000	-0.3840	-0.2360
1	152	24.3300	23.8500	21.9200	2.7020	2.6880	2.4790	-0.4800	-2.4100	-0.0140	-0.2230
1	153	21.8800	22.7400	28.1500	2.4090	2.4980	3.2010	0.8600	6.2700	0.0890	0.7920
1	154	23.3500	22.1700	23.8100	2.5900	2.4330	2.7320	-1.1800	0.4600	-0.1570	0.1420
1	155	23.5000	No test	No test	2.7550	No test	No test	No test	No test	No test	No test
1	156	22.6400	26.2200	27.6100	2.5300	3.0670	3.2680	3.5800	4.9700	0.5370	0.7380
1	157	25.5000	27.6300	24.8100	2.8580	3.1120	2.7980	2.1300	-0.6900	0.2540	-0.0600
1	158	21.0100	22.0800	23.7000	2.1830	2.3400	2.5850	1.0700	2.6900	0.1570	0.4020
1	159	23.6400	23.0200	22.9400	2.4790	2.4610	2.5190	-0.6200	-0.7000	-0.0180	0.0400
1	160	26.8000	22.3900	21.9900	3.3650	2.7050	2.7020	-4.4100	-4.8100	-0.6600	-0.6630
1	161	24.0500	25.0300	27.4600	2.7290	2.8930	3.3800	0.9800	3.4100	0.1640	0.6510
1	162	28.0700	23.4600	27.4900	3.0720	2.5490	3.1270	-4.6100	-0.5800	-0.5230	0.0550
1	163	26.7800	22.6700	27.0300	3.0350	2.5210	3.1400	-4.1100	0.2500	-0.5140	0.1050
1	164	22.9000	21.9900	25.8800	2.5570	2.4220	3.0570	-0.9100	2.9800	-0.1350	0.5000
1	165	24.3400	22.2600	25.1100	2.6560	2.3850	2.8190	-2.0800	0.7700	-0.2710	0.1630
1	166	25.9000	22.6700	24.8700	3.1040	2.5910	3.0650	-3.2300	-1.0300	-0.5130	-0.0390
1	167	26.4300	21.9300	22.6200	3.3150	2.6850	2.8470	-4.5000	-3.8100	-0.6300	-0.4680
1	168	24.9500	22.8600	25.6900	2.8380	2.5500	3.0530	-2.0900	0.7400	-0.2880	0.2150
1	169	23.4200	22.2500	27.0900	2.7590	2.5890	3.3470	-1.1700	3.6700	-0.1700	0.5880
1	170	24.9100	22.6800	24.8800	2.7200	2.4210	2.8240	-2.2300	-0.0300	-0.2990	0.1040
1	171	25.3600	22.2100	23.2000	2.8220	2.4180	3.6840	-3.1500	-2.1600	-0.4040	0.8620

Figure F-1. Vendor 1 Refresh Times Measured at V_{CC}=5.5 volts (Random bits)

1	172	25.2600	23.2000	23.6600	2.8620	2.5650	2.6620	-2.0600	-1.6000	-0.2970	-0.2000
1	173	23.3500	21.4000	22.4400	2.5120	2.2880	2.4300	-1.9500	-0.9100	-0.2240	-0.0820
1	174	23.9800	21.0600	22.7200	2.8920	2.5010	2.7210	-2.9200	-1.2600	-0.3910	-0.1710
1	175	24.2800	21.0200	25.6000	2.8860	2.4610	3.2830	-3.2600	1.3200	-0.4250	0.3970
1	176	25.7100	21.1200	21.5800	2.9010	2.2920	2.4550	-4.5900	-4.1300	-0.6090	-0.4460
1	177	24.6000	22.1400	22.1900	2.8780	2.5160	2.7000	-2.4600	-2.4100	-0.3620	-0.1780
1	178	22.7100	21.2700	22.7000	2.9050	2.7310	3.1080	-1.4400	-0.0100	-0.1740	0.2030
1	179	24.4600	25.9700	27.6200	2.7050	2.8960	3.1820	1.5100	3.1600	0.1910	0.4770
1	180	22.5300	25.0900	26.6500	2.8540	3.2670	3.7440	2.5600	4.1200	0.4130	0.8900
1	181	22.7900	24.6300	21.7600	2.6400	2.9100	2.5860	1.8400	-1.0300	0.2700	-0.0540
1	182	27.9000	27.8400	26.3600	3.3110	3.2650	3.1690	-0.0600	-1.5400	-0.0460	-0.1420
1	183	24.7200	25.6700	27.2700	2.6900	2.8050	3.0210	0.9500	2.5500	0.1150	0.3310
1	184	23.8400	23.6600	26.9400	2.8830	2.8300	3.4410	-0.1800	3.1000	-0.0530	0.5580
1	185	25.1800	24.9900	27.5600	2.9870	3.0230	3.5460	-0.1900	2.3800	0.0360	0.5590
1	186	24.0100	24.0400	22.8900	3.0430	3.0810	2.9440	0.0300	-1.1200	0.0380	-0.0990
1	187	23.4300	23.6000	22.5900	3.1940	3.3430	3.3120	0.1700	-0.8400	0.1490	0.1180
1	189	23.1300	22.9400	24.1600	2.4590	2.4460	2.6240	-0.1900	1.0300	-0.0130	0.1650
1	190	25.1100	23.9900	24.3500	2.7660	2.6310	2.7050	-1.1200	-0.7600	-0.1350	-0.0610
1	191	25.3400	24.8700	26.2700	2.7440	2.7040	2.9680	-0.4700	0.9300	-0.0400	0.2240
1	192	22.5800	23.9100	24.3900	2.5250	2.7080	2.7840	1.3300	1.8100	0.1830	0.2590
1	193	23.2400	25.6300	22.7900	2.5970	2.9620	2.6600	2.3900	-0.4500	0.3650	0.0630
1	194	25.7200	23.6300	25.7000	3.0200	2.7190	3.1700	-2.0900	-0.0200	-0.3010	0.1500
1	195	23.5800	24.9600	21.2300	2.9720	3.2810	2.7470	1.3800	-2.3500	0.3090	-0.2250
1	196	24.9000	25.7900	24.0700	2.9980	3.1670	2.9690	0.8900	-0.8300	0.1690	-0.0290
1	197	24.5800	25.3700	23.5400	2.7900	2.9280	2.6450	0.7900	-1.0400	0.1380	-0.1450
1	198	26.4000	24.5200	22.4700	2.8800	2.6500	2.4310	-1.8800	-3.9300	-0.2300	-0.4490
1	199	23.7600	22.7400	21.9300	3.1930	2.9890	3.1120	-1.0200	-1.8300	-0.2040	-0.0810
1	200	26.5400	24.4100	21.8100	3.1760	2.8880	2.5140	-2.1300	-4.7300	-0.2880	-0.6620
1	201	25.5100	25.1900	23.9000	3.0670	3.0400	2.9390	-0.3200	-1.6100	-0.0270	-0.1280
1	202	23.9500	24.6000	25.6400	3.0070	2.7430	2.9310	0.6500	1.6900	-0.2640	-0.0760
1	203	26.4200	25.1300	24.1100	2.9800	2.8420	2.7710	-1.2900	-2.3100	-0.1380	-0.2090
1	204	24.4500	24.9700	22.7200	3.1490	3.3020	3.6390	0.5200	-1.7300	0.1530	0.4900
1	205	22.8700	25.4400	21.8600	2.9800	3.3730	2.9450	2.5700	-1.0100	0.3930	-0.0350
1	206	22.2000	23.9100	20.6700	2.3550	2.5950	2.2590	1.7100	-1.5300	0.2400	-0.0960
1	207	21.5400	25.5100	25.4000	2.4430	3.0710	3.1020	3.9700	3.8600	0.6280	0.6590
1	208	22.6100	24.7100	24.5700	2.4690	2.7410	2.7580	2.1000	1.9600	0.2720	0.2890
1	209	26.3500	25.2600	23.1300	2.8750	2.7280	2.4860	-1.0900	-3.2200	-0.1470	-0.3890
1	210	23.1100	24.1200	21.5800	2.5210	2.7280	2.4240	1.0100	-1.5300	0.2070	-0.0970
1	211	25.3600	25.9500	24.4800	2.8620	3.0730	2.9240	0.5900	-0.8800	0.2110	0.0620
1	212	24.5100	25.5900	24.3100	2.9840	3.1830	3.0010	1.0800	-0.2000	0.1990	0.0170

Figure F-1. Vendor 1 Refresh Times Measured at V_{CC}=5.5 volts (Random bits)

Vendor 1 Refresh times (seconds) Measured at Vcc=5.5 volts

1000 Worst case bits

		Mean			Sigma			Mean delta		Sigma delta	
Cell	S/N	0 hrs	160 hrs	4000 hrs	0 hrs	160 hrs	4000 hrs	0 to 160	0 to 4000	0 to 160	0 to 4000
1	130	19.2000	15.7000	15.1900	3.2580	2.3950	3.0710	-3.5000	-4.0100	-0.8630	-0.1870
1	131	16.3000	6.3100	2.7040	3.6590	2.3950	1.4840	-9.9900	-13.5960	-1.2640	-2.1750
1	132	18.2200	16.2200	18.2900	2.6680	1.9590	2.3630	-2.0000	0.0700	-0.7090	-0.3050
1	133	17.3500	17.7400	16.0400	2.9790	3.3590	2.5910	0.3900	-1.3100	0.3800	-0.3880
1	134	17.2900	15.7100	15.9800	3.0410	2.4630	2.3440	-1.5800	-1.3100	-0.5780	-0.6970
1	135	19.1500	16.4600	17.3000	1.6170	1.2680	1.3800	-2.6900	-1.8500	-0.3490	-0.2370
1	137	18.0500	15.5800	16.1300	2.9700	2.2360	2.6580	-2.4700	-1.9200	-0.7340	-0.3120
1	139	18.6300	16.2900	17.4300	2.1620	1.6990	1.8530	-2.3400	-1.2000	-0.4630	-0.3090
1	140	18.3700	16.8900	16.6600	1.5580	1.3190	1.3460	-1.4800	-1.7100	-0.2390	-0.2120
1	141	17.8900	17.2500	16.8800	1.8070	1.6600	1.5980	-0.6400	-1.0100	-0.1470	-0.2090
1	142	18.9400	18.0100	17.9600	2.6780	2.4890	2.5680	-0.9300	-0.9800	-0.1890	-0.1100
1	143	18.2500	16.7800	18.1900	2.4100	2.0500	2.3860	-1.4700	-0.0600	-0.3600	-0.0240
1	144	20.4600	18.7700	22.8900	2.4400	2.1260	2.7890	-1.6900	2.4300	-0.3140	0.3490
1	145	19.5300	16.2100	19.7300	2.8260	2.5770	3.0490	-3.3200	0.2000	-0.2490	0.2230
1	146	17.9700	16.0900	18.7900	2.9240	2.2690	2.7720	-1.8800	0.8200	-0.6550	-0.1520
1	147	18.9400	17.7700	18.7300	2.0750	1.7830	1.9310	-1.1700	-0.2100	-0.2920	-0.1440
1	148	19.5900	18.8400	18.4400	2.3510	2.1700	2.1080	-0.7500	-1.1500	-0.1810	-0.2430
1	149	18.2600	17.2700	20.0600	2.0860	1.8570	2.2960	-0.9900	1.8000	-0.2290	0.2100
1	150	17.2900	16.7500	16.0600	2.5960	2.3480	1.8050	-0.5400	-1.2300	-0.2480	-0.7910
1	151	19.6500	17.5200	17.6600	2.5030	2.2210	2.1490	-2.1300	-1.9900	-0.2820	-0.3540
1	152	17.8500	17.5600	16.1000	2.4430	2.1470	1.9290	-0.2900	-1.7500	-0.2960	-0.5140
1	153	16.5000	17.2100	21.0400	1.7390	1.7390	2.3140	0.7100	4.5400	0.0000	0.5750
1	154	17.4700	16.6400	17.7000	1.9560	1.7690	1.8520	-0.8300	0.2300	-0.1870	-0.1040
1	155	17.3300	No test	No test	2.4030	No test	No test	No test	No test	No test	No test
1	156	17.2200	19.7900	20.6600	1.3800	1.6800	1.7870	2.5700	3.4400	0.3000	0.4070
1	157	19.1500	20.7200	18.6400	2.1270	2.2290	1.8900	1.5700	-0.5100	0.1020	-0.2370
1	158	16.2200	16.9500	18.1200	1.3930	1.3980	1.5270	0.7300	1.9000	0.0050	0.1340
1	159	17.9200	17.4800	17.3100	1.8210	1.6770	1.7510	-0.4400	-0.6100	-0.1440	-0.0700
1	160	19.2200	16.2900	15.9500	2.6790	1.8970	1.7930	-2.9300	-3.2700	-0.7820	-0.8860
1	161	17.8200	18.5000	19.9400	2.5040	2.4970	2.8280	0.6800	2.1200	-0.0070	0.3240
1	162	21.1500	17.8300	20.6300	2.1230	1.5610	2.0280	-3.3200	-0.5200	-0.5620	-0.0950
1	163	19.9800	16.9800	20.0500	2.5130	2.0620	2.3340	-3.0000	0.0700	-0.4510	-0.1790
1	164	16.6700	16.0500	18.5600	2.3100	2.0330	2.5640	-0.6200	1.8900	-0.2770	0.2540
1	165	17.9000	16.4800	18.3900	2.3020	1.9360	2.2860	-1.4200	0.4900	-0.3660	-0.0160
1	166	18.3700	16.3100	17.6300	2.9690	2.3280	2.6960	-2.0600	-0.7400	-0.6410	-0.2730
1	167	18.7900	15.8400	16.1300	2.5860	2.0340	1.9070	-2.9500	-2.6600	-0.5520	-0.6790
1	168	18.3900	16.9800	18.8900	2.4800	2.0280	2.1580	-1.4100	0.5000	-0.4520	-0.3220
1	169	16.5500	15.7400	18.8400	2.8060	2.5890	3.3510	-0.8100	2.2900	-0.2170	0.5450
1	170	18.7100	17.1500	18.5500	2.0310	1.6660	1.9100	-1.5600	-0.1600	-0.3650	-0.1210
1	171	19.5800	17.1800	17.0100	1.7950	1.4510	3.3910	-2.4000	-2.5700	-0.3440	1.5960

Figure F-2. Vendor 1 Refresh Times Measured at V_{CC}=5.5 volts (Worst-case bits)

1	172	18.9600	17.5400	17.7700	2.1560	1.7710	1.7770	-1.4200	-1.1900	-0.3850	-0.3790
1	173	17.9700	16.4800	17.1500	1.7150	1.4410	1.5150	-1.4900	-0.8200	-0.2740	-0.2000
1	174	17.3700	15.3300	16.5200	2.5020	2.3460	2.0680	-2.0400	-0.8500	-0.1560	-0.4340
1	175	17.7700	15.4800	18.4300	2.4550	2.0360	2.5690	-2.2900	0.6600	-0.4190	0.1140
1	176	18.7300	15.7000	15.7900	2.5320	1.8020	1.8430	-3.0300	-2.9400	-0.7300	-0.6890
1	177	17.0200	15.4900	15.0700	2.8270	2.3580	2.7150	-1.5300	-1.9500	-0.4690	-0.1120
1	178	14.2600	13.5100	13.8800	3.0160	2.6590	3.2040	-0.7500	-0.3800	-0.3570	0.1880
1	179	18.4000	19.4900	20.6100	2.1970	2.2910	2.4430	1.0900	2.2100	0.0940	0.2460
1	180	14.5900	16.2400	16.6000	3.1970	3.2910	3.8390	1.6500	2.0100	0.0940	0.6420
1	181	16.2100	17.3400	15.4600	2.5590	2.8610	2.1780	1.1300	-0.7500	0.3020	-0.3810
1	182	19.0500	19.1300	18.1300	3.1870	2.9940	2.8250	0.0800	-0.9200	-0.1930	-0.3620
1	183	18.8700	19.5000	20.5600	1.9330	1.9000	2.1990	0.6300	1.6900	-0.0330	0.2660
1	184	16.7400	16.6800	18.5800	2.7150	2.5900	3.1200	-0.0600	1.8400	-0.1250	0.4050
1	185	17.3300	17.1600	18.5500	3.1960	3.2310	3.6830	-0.1700	1.2200	0.0350	0.4870
1	186	16.8400	16.8800	16.0000	2.8340	2.7950	2.5740	0.0400	-0.8400	-0.0390	-0.2600
1	187	14.3100	14.1800	13.3300	3.2530	3.3910	3.2990	-0.1300	-0.9800	0.1380	0.0460
1	189	17.9200	17.7500	18.6000	1.8650	1.7770	1.8060	-0.1700	0.6800	-0.0880	-0.0590
1	190	21.3000	18.4200	18.6100	2.5170	1.4980	1.5330	-2.8800	-2.6900	-1.0190	-0.9840
1	191	21.6300	18.9900	19.8500	2.4160	1.7800	2.0100	-2.6400	-1.7800	-0.6360	-0.4060
1	192	19.1200	20.1700	20.5100	2.6170	2.8230	2.7710	1.0500	1.3900	0.2060	0.1540
1	193	19.5900	21.5900	19.0200	2.9960	3.4180	3.0560	2.0000	-0.5700	0.4220	0.0600
1	194	19.8000	18.2900	19.4100	4.3000	3.8090	4.5410	-1.5100	-0.3900	-0.4910	0.2410
1	195	17.5000	18.2700	15.6200	4.2370	4.5820	3.6340	0.7700	-1.8800	0.3450	-0.6030
1	196	19.6200	20.3400	18.8500	3.9640	4.1150	3.8180	0.7200	-0.7700	0.1510	-0.1460
1	197	19.0300	19.6500	18.3500	3.7240	3.8210	3.3350	0.6200	-0.6800	0.0970	-0.3890
1	198	21.8300	20.3800	18.6800	3.1630	2.7700	2.3630	-1.4500	-3.1500	-0.3930	-0.8000
1	199	17.6200	16.8700	15.8400	4.5010	4.1520	4.1830	-0.7500	-1.7800	-0.3490	-0.3180
1	200	21.8400	20.1500	18.0100	3.6350	3.1600	2.5830	-1.6900	-3.8300	-0.4750	-1.0520
1	201	19.5600	19.4200	18.2600	4.0370	3.8570	3.7050	-0.1400	-1.3000	-0.1800	-0.3320
1	202	18.9400	20.6100	21.5100	3.3020	2.8630	2.9220	1.6700	2.5700	-0.4390	-0.3800
1	203	20.2100	19.2700	18.4700	4.2150	3.8620	3.6280	-0.9400	-1.7400	-0.3530	-0.5870
1	204	20.0700	20.2600	16.9200	3.6910	3.7480	3.8660	0.1900	-3.1500	0.0570	0.1750
1	205	16.7000	18.5800	15.8900	4.2590	4.5930	3.8010	1.8800	-0.8100	0.3340	-0.4580
1	206	16.8000	18.2100	16.0600	3.2880	3.3400	2.4980	1.4100	-0.7400	0.0520	-0.7900
1	207	16.8100	19.4600	19.3100	2.6780	3.6100	3.4660	2.6500	2.5000	0.9320	0.7880
1	208	18.6100	20.3700	20.2100	2.8410	3.1440	3.0230	1.7600	1.6000	0.3030	0.1820
1	209	22.6100	21.6900	19.7900	3.2530	3.0300	2.6060	-0.9200	-2.8200	-0.2230	-0.6470
1	210	19.6200	20.4700	18.2900	2.6130	2.7380	2.2810	0.8500	-1.3300	0.1250	-0.3320
1	211	18.4300	18.5200	17.3900	2.5390	2.7080	2.5790	0.0900	-1.0400	0.1690	0.0400
1	212	17.3900	18.0900	17.2500	2.7880	2.9030	2.5490	0.7000	-0.1400	0.1150	-0.2390

Figure F-2. Vendor 1 Refresh Times Measured at V_{CC}=5.5 volts (Worst-case bits)

Vendor 1 Refresh times (seconds) Measured at Vcc=6.0 volts

1000 Random bits

		Mean			Sigma			Mean delta		Sigma delta	
Cell	S/N	0 hrs	160 hrs	4000 hrs	0 hrs	160 hrs	4000 hrs	0 to 160	0 to 4000	0 to 160	0 to 4000
1	130	26.6100	21.3500	21.6000	3.9580	3.0450	4.2540	-5.2600	-5.0100	-0.9130	0.2960
1	131	23.9800	11.5800	6.5030	4.5830	6.3280	5.2580	-12.4000	-17.4770	1.7450	0.6750
1	133	23.7700	24.8300	23.6500	3.3590	3.6000	3.3510	1.0600	-0.1200	0.2410	-0.0080
1	132	24.0800	21.1400	21.8800	3.4150	2.8470	3.1320	-2.9400	-2.2000	-0.5680	-0.2830
1	134	24.0500	21.5200	21.7700	3.4150	3.0020	3.1170	-2.5300	-2.2800	-0.4130	-0.2980
1	135	24.0300	20.7300	21.5900	2.9300	2.4670	2.5760	-3.3000	-2.4400	-0.4630	-0.3540
1	137	24.9700	21.1900	22.2300	3.6620	2.9780	3.2860	-3.7800	-2.7400	-0.6840	-0.3760
1	139	24.3300	21.1000	22.8500	3.3040	2.7660	3.0330	-3.2300	-1.4800	-0.5380	-0.2710
1	140	23.0500	21.1500	21.0300	2.8170	2.5580	2.5890	-1.9000	-2.0200	-0.2590	-0.2280
1	141	22.3500	21.5300	21.0800	2.8210	2.6930	2.6520	-0.8200	-1.2700	-0.1280	-0.1690
1	142	22.1000	21.0800	21.1400	3.6800	3.4460	3.5510	-1.0200	-0.9600	-0.2340	-0.1290
1	143	24.1300	21.9700	24.2300	3.2230	2.8530	3.2580	-2.1600	0.1000	-0.3700	0.0350
1	144	23.3100	21.4600	26.0600	2.8290	2.5650	3.8380	-1.8500	2.7500	-0.2640	1.0090
1	145	26.3300	21.8600	26.8300	3.7020	2.9040	3.8950	-4.4700	0.5000	-0.7980	0.1930
1	146	24.3700	20.9000	24.6100	3.4000	2.8440	3.6460	-3.4700	0.2400	-0.5560	0.2460
1	147	24.0000	22.4000	24.0300	3.2210	2.9110	3.2110	-1.6000	0.0300	-0.3100	-0.0100
1	148	22.3500	21.3900	21.0200	2.7730	2.6100	2.5530	-0.9600	-1.3300	-0.1630	-0.2200
1	149	23.8600	22.4300	26.3700	3.1230	2.8560	3.5370	-1.4300	2.5100	-0.2670	0.4140
1	150	22.6400	21.8100	20.5600	2.9130	2.7740	2.6210	-0.8300	-2.0800	-0.1390	-0.2920
1	151	24.8900	22.0500	22.2400	4.3060	3.6910	3.7870	-2.8400	-2.6500	-0.6150	-0.5190
1	152	23.3500	22.9200	21.1100	3.1370	3.0890	2.8170	-0.4300	-2.2400	-0.0480	-0.3200
1	153	21.2600	21.9600	27.0900	2.6850	2.7830	3.6740	0.7000	5.8300	0.0980	0.9890
1	154	22.6300	21.4200	22.9100	3.0060	2.8060	3.0000	-1.2100	0.2800	-0.2000	-0.0060
1	155	22.1300	No test	No test	3.5820	No test	No test	No test	No test	No test	No test
1	156	21.4000	24.6300	25.6900	3.2200	3.9630	4.5630	3.2300	4.2900	0.7430	1.3430
1	157	24.6300	26.7000	23.8700	3.2860	3.6140	3.0940	2.0700	-0.7600	0.3280	-0.1920
1	158	20.4900	21.4400	22.7900	2.4900	2.5600	2.7700	0.9500	2.3000	0.0700	0.2800
1	159	22.8700	22.1700	22.0900	2.9370	2.8280	2.7950	-0.7000	-0.7800	-0.1090	-0.1420
1	160	25.1400	21.1000	20.6100	4.3030	3.3670	3.2940	-4.0400	-4.5300	-0.9360	-1.0090
1	161	23.1700	24.0600	26.2500	3.1390	3.3170	3.8580	0.8900	3.0800	0.1780	0.7190
1	162	27.2100	22.7200	26.4900	3.4940	2.8370	3.3930	-4.4900	-0.7200	-0.6570	-0.1010
1	163	25.8900	22.0000	25.9100	3.4950	2.8340	3.4970	-3.8900	0.0200	-0.6610	0.0020
1	164	22.1300	21.2100	24.8000	2.9900	2.8050	3.5480	-0.9200	2.6700	-0.1850	0.5580
1	165	23.5700	21.4600	24.1600	3.0940	2.7490	3.1940	-2.1100	0.5900	-0.3450	0.1000
1	166	25.0100	21.7500	23.8700	3.6540	3.0320	3.4780	-3.2600	-1.1400	-0.6220	-0.1760
1	167	24.6400	20.6000	21.1000	4.3120	3.3860	3.5780	-4.0400	-3.5400	-0.9260	-0.7340
1	168	24.1800	21.9200	24.5300	3.3070	2.9390	3.4290	-2.2600	0.3500	-0.3680	0.1220
1	169	22.3900	21.2600	25.7600	3.3910	3.1490	4.1480	-1.1300	3.3700	-0.2420	0.7570
1	170	24.0700	21.7100	23.7700	3.0760	2.7390	3.1670	-2.3600	-0.3000	-0.3370	0.0910
1	171	24.5100	21.4600	21.3300	3.1770	2.6640	4.4000	-3.0500	-3.1800	-0.5130	1.2230

Figure F-3. Vendor 1 Refresh Times Measured at V_{CC}=6.0 volts (Random bits)

1	172	24.4100	22.3600	22.7100	3.2980	2.9530	2.9630	-2.0500	-1.7000	-0.3450	-0.3350
1	173	22.5500	20.8000	21.5600	2.8030	2.5700	2.6420	-1.7500	-0.9900	-0.2330	-0.1610
1	174	22.5200	19.8800	21.3200	3.8050	3.1660	3.4910	-2.6400	-1.2000	-0.6390	-0.3140
1	175	22.8000	19.8000	23.7300	3.8340	3.0990	4.2230	-3.0000	0.9300	-0.7350	0.3890
1	176	24.8300	20.3800	20.8500	3.4010	2.6340	2.7750	-4.4500	-3.9800	-0.7670	-0.6260
1	177	23.5800	21.2800	20.9700	3.4240	2.9550	3.1810	-2.3000	-2.6100	-0.4690	-0.2430
1	178	21.1800	19.8800	20.9200	3.8890	3.5570	4.1270	-1.3000	-0.2600	-0.3320	0.2380
1	179	23.6800	25.1700	26.7800	3.1160	3.3480	3.5310	1.4900	3.1000	0.2320	0.4150
1	180	20.8200	23.0900	24.2000	3.8480	4.5390	5.2160	2.2700	3.3800	0.6910	1.3680
1	181	21.9000	23.5300	20.8000	3.0900	3.4070	3.0140	1.6300	-1.1000	0.3170	-0.0760
1	182	26.9500	26.9100	25.6500	3.9450	3.9550	3.7060	-0.0400	-1.3000	0.0100	-0.2390
1	183	23.9900	24.7700	26.4600	3.0940	3.2570	3.4600	0.7800	2.4700	0.1630	0.3660
1	184	22.3300	22.1500	25.0700	3.7840	3.7430	4.5570	-0.1800	2.7400	-0.0410	0.7730
1	185	24.1700	23.9500	26.2600	3.6110	3.5690	4.2670	-0.2200	2.0900	-0.0420	0.6560
1	186	22.3100	22.3100	21.1500	4.1010	4.1450	3.9520	0.0000	-1.1600	0.0440	-0.1490
1	187	21.5000	21.5300	20.3200	4.2680	4.4550	4.4030	0.0300	-1.1800	0.1870	0.1350
1	189	22.3700	22.0800	23.2800	2.7960	2.7960	2.9090	-0.2900	0.9100	0.0000	0.1130
1	190	24.2800	23.1200	23.4700	3.0940	2.9290	2.9190	-1.1600	-0.8100	-0.1650	-0.1750
1	191	24.4500	23.9600	25.3800	3.1250	3.0420	3.2490	-0.4900	0.9300	-0.0830	0.1240
1	192	21.7600	22.9500	23.3500	2.9820	3.1600	3.2320	1.1900	1.5900	0.1780	0.2500
1	193	22.3400	24.5600	21.7800	3.1060	3.4820	3.1850	2.2200	-0.5600	0.3760	0.0790
1	194	24.6600	22.6200	24.5100	3.6110	3.2880	3.8030	-2.0400	-0.1500	-0.3230	0.1920
1	195	21.8800	22.9800	19.5800	4.0460	4.4640	3.7150	1.1000	-2.3000	0.4180	-0.3310
1	196	23.9500	24.7600	23.0200	3.5060	3.7230	3.4160	0.8100	-0.9300	0.2170	-0.0900
1	197	23.8000	24.4400	22.6400	3.4300	3.4320	3.0970	0.6400	-1.1600	0.0020	-0.3330
1	198	25.5600	23.6600	21.6300	3.3040	2.9760	2.6730	-1.9000	-3.9300	-0.3280	-0.6310
1	199	21.7700	20.7700	19.7000	4.3120	4.0980	4.2020	-1.0000	-2.0700	-0.2140	-0.1100
1	200	24.9700	23.0400	20.5600	4.2010	3.7100	3.1400	-1.9300	-4.4100	-0.4910	-1.0610
1	201	24.4700	24.2100	22.8600	3.5930	3.5620	3.3790	-0.2600	-1.6100	-0.0310	-0.2140
1	202	22.1600	23.7000	24.6200	4.0100	3.0990	3.2400	1.5400	2.4600	-0.9110	-0.7700
1	203	25.3700	24.1100	22.8800	3.6170	3.3740	3.5100	-1.2600	-2.4900	-0.2430	-0.1070
1	204	23.1900	23.4000	19.8200	3.8430	4.2050	4.9830	0.2100	-3.3700	0.3620	1.1400
1	205	21.3500	23.6400	20.1500	3.8340	4.4750	3.7930	2.2900	-1.2000	0.6410	-0.0410
1	206	21.4500	22.8400	19.6200	2.7260	3.0180	2.5520	1.3900	-1.8300	0.2920	-0.1740
1	207	20.4700	24.0400	23.8400	3.1390	3.9250	3.8840	3.5700	3.3700	0.7860	0.7450
1	208	21.8200	23.8200	23.7400	2.7560	3.1100	3.1120	2.0000	1.9200	0.3540	0.3560
1	209	25.4300	24.3000	22.1500	3.2300	3.0260	3.0120	-1.1300	-3.2800	-0.2040	-0.2180
1	210	22.2300	23.2700	20.7500	2.7490	2.9360	2.5280	1.0400	-1.4800	0.1870	-0.2210
1	211	24.5100	24.8100	23.2200	3.3610	3.7530	3.6360	0.3000	-1.2900	0.3920	0.2750
1	212	22.8900	23.9900	22.7700	4.0590	4.2720	3.9650	1.1000	-0.1200	0.2130	-0.0940

Figure F-3. Vendor 1 Refresh Times Measured at V_{CC}=6.0 volts (Random bits)

Vendor 1 Refresh times (seconds) Measured at Vcc=6.0 volts

1000 Worst case bits

		Mean			Sigma			Mean delta		Sigma delta	
Cell	S/N	0 hrs	160 hrs	4000 hrs	0 hrs	160 hrs	4000 hrs	0 to 160	0 to 4000	0 to 160	0 to 4000
1	130	16.4000	13.3400	11.2000	5.2730	4.0680	4.4840	-3.0600	-5.2000	-1.2050	-0.7890
1	131	11.4600	2.1720	0.8606	5.5610	1.5140	0.8461	-9.2880	-10.5994	-4.0500	-4.7179
1	132	16.6200	15.6100	16.4800	4.0710	4.9010	3.8880	-1.0100	-0.1400	0.8300	-0.1830
1	133	15.1700	14.8900	13.8400	4.7780	3.4600	4.2770	-0.2800	-1.3300	-1.3180	-0.5010
1	134	14.9400	13.6000	13.5900	4.7990	4.1550	4.1330	-1.3400	-1.3500	-0.6440	-0.6660
1	135	18.1100	15.6800	16.2800	2.3520	2.0920	2.1480	-2.4300	-1.8300	-0.5600	-0.5040
1	137	15.3900	13.2700	13.6000	4.9750	4.0260	4.3660	-2.1200	-1.7900	-0.9490	-0.6090
1	139	16.9900	14.8300	15.9700	3.6430	3.0040	3.0990	-2.1600	-1.0200	-0.6390	-0.5440
1	140	17.2900	15.9100	15.7300	2.5020	2.1730	2.1420	-1.3800	-1.5600	-0.3290	-0.3600
1	141	16.8200	16.2500	15.8600	2.7750	2.5220	2.4720	-0.5700	-0.9600	-0.2530	-0.3030
1	142	16.5200	15.8000	15.6400	3.7570	3.4920	3.5240	-0.7200	-0.8800	-0.2650	-0.2330
1	143	16.2300	14.8700	16.2200	4.0930	3.5720	3.9160	-1.3600	-0.0100	-0.5210	-0.1770
1	144	19.6800	18.0600	21.8100	2.9880	2.6500	3.8530	-1.6200	2.1300	-0.3380	0.8650
1	145	17.4000	14.6900	17.4600	4.8040	3.8280	4.9990	-2.7100	0.0600	-0.9760	0.1950
1	146	16.0400	13.9600	16.0400	4.4700	3.6450	4.2510	-2.0800	0.0000	-0.8250	-0.2190
1	147	17.7400	16.5700	17.6100	3.2680	2.9580	3.0990	-1.1700	-0.1300	-0.3100	-0.1690
1	148	19.0100	18.1600	17.7700	2.8380	2.6160	2.4530	-0.8500	-1.2400	-0.2220	-0.3850
1	149	16.5200	15.5900	18.1300	3.6230	3.2990	3.8940	-0.9300	1.6100	-0.3240	0.2710
1	150	16.1300	15.5400	14.7200	3.5960	3.3640	3.1200	-0.5900	-1.4100	-0.2320	-0.4760
1	151	16.4800	14.8100	14.7600	4.3160	3.7310	3.5940	-1.6700	-1.7200	-0.5850	-0.7220
1	152	16.2000	16.0000	14.6800	3.7600	3.6530	3.2470	-0.2000	-1.5200	-0.1070	-0.5130
1	153	15.4600	15.9100	19.3300	2.9320	2.9670	3.8690	0.4500	3.8700	0.0350	0.9370
1	154	16.1400	15.3100	16.3600	3.3280	3.0550	3.1150	-0.8300	0.2200	-0.2730	-0.2130
1	155	14.7600	No test	No test	3.9050	No test	No test	No test	No test	No test	No test
1	156	15.2300	17.3000	17.7700	2.1950	2.6420	2.9480	2.0700	2.5400	0.4470	0.7530
1	157	17.7600	19.1400	17.2400	3.2770	3.5980	2.9730	1.3800	-0.5200	0.3210	-0.3040
1	158	15.5200	16.1300	17.0900	2.1810	2.2630	2.2480	0.6100	1.5700	0.0820	0.0670
1	159	16.6300	16.0900	15.9600	3.0830	2.8800	2.7060	-0.5400	-0.6700	-0.2030	-0.3770
1	160	15.9700	13.6700	13.2500	4.4290	3.5260	3.2590	-2.3000	-2.7200	-0.9030	-1.1700
1	161	16.1800	16.6700	17.8900	3.8890	3.9640	4.2790	0.4900	1.7100	0.0750	0.3900
1	162	19.8200	16.6900	19.2900	3.5270	2.7220	3.1460	-3.1300	-0.5300	-0.8050	-0.3810
1	163	18.5300	15.8400	18.4900	3.9630	3.1770	3.7260	-2.6900	-0.0400	-0.7860	-0.2370
1	164	14.9600	14.4200	16.4400	3.6970	3.4370	4.1410	-0.5400	1.4800	-0.2600	0.4440
1	165	16.0800	14.7900	16.5400	3.9200	3.3930	3.7220	-1.2900	0.4600	-0.5270	-0.1980
1	166	16.1800	14.3200	15.4800	4.7380	3.9010	4.2870	-1.8600	-0.7000	-0.8370	-0.4510
1	167	15.4300	13.2100	13.2400	4.2080	3.3290	3.2860	-2.2200	-2.1900	-0.8790	-0.9220
1	168	16.8000	15.3100	16.9200	4.1260	3.5420	3.7610	-1.4900	0.1200	-0.5840	-0.3650
1	169	14.1300	13.5000	15.8600	4.4870	4.1330	5.2210	-0.6300	1.7300	-0.3540	0.7340
1	170	17.4000	15.7400	17.0500	3.2170	2.8250	3.0900	-1.6600	-0.3500	-0.3920	-0.1270
1	171	18.5200	16.2300	15.1000	2.7610	2.2360	4.1010	-2.2900	-3.4200	-0.5250	1.3400

Figure F-4. Vendor 1 Refresh Times Measured at V_{CC}=6.0 volts (Worst-case bits)

1	172	17.6200	16.2100	16.4400	3.3450	2.9140	2.8090	-1.4100	-1.1800	-0.4310	-0.5360
1	173	16.9300	15.6200	16.1400	2.6750	2.3830	2.3270	-1.3100	-0.7900	-0.2920	-0.3480
1	174	14.6300	13.1500	13.8600	4.0080	3.3810	3.4710	-1.4800	-0.7700	-0.6270	-0.5370
1	175	15.0500	13.2700	15.2100	3.9070	3.1980	3.9090	-1.7800	0.1600	-0.7090	0.0020
1	176	16.8600	14.0500	14.3200	4.1120	3.1780	3.1510	-2.8100	-2.5400	-0.9340	-0.9610
1	177	14.6100	13.3900	12.7000	4.6580	3.9180	4.3220	-1.2200	-1.9100	-0.7400	-0.3360
1	178	10.2700	9.8450	9.7220	4.6660	4.2870	4.5620	-0.4250	-0.5480	-0.3790	-0.1040
1	179	16.9800	18.0600	19.1200	3.6520	3.8540	3.9450	1.0800	2.1400	0.2020	0.2930
1	180	10.8800	11.7200	11.4700	4.4310	4.9690	5.1650	0.8400	0.5900	0.5380	0.7340
1	181	14.1400	15.0700	13.3100	4.3330	4.5870	3.9180	0.9300	-0.8300	0.2540	-0.4150
1	182	16.5300	16.5100	15.8400	5.1910	5.0770	4.6550	-0.0200	-0.6900	-0.1140	-0.5360
1	183	17.4800	17.9300	19.1500	3.4820	3.5700	3.5220	0.4500	1.6700	0.0880	0.0400
1	184	13.4700	13.3700	14.6200	4.4600	4.3620	4.9580	-0.1000	1.1500	-0.0980	0.4980
1	185	14.7000	14.5600	15.4800	5.0710	5.0070	5.7380	-0.1400	0.7800	-0.0640	0.6670
1	186	13.4300	13.3700	2.6000	4.2940	4.2740	3.8960	-0.0600	-0.8300	-0.0200	-0.3980
1	187	9.7640	9.4500	8.7080	4.7000	4.7150	4.3650	-0.3140	-1.0560	0.0150	-0.3350
1	189	16.9600	16.7300	17.5500	2.7870	2.6960	2.6940	-0.2300	0.5900	-0.0910	-0.0930
1	190	19.8900	17.3800	17.5800	3.5900	2.4560	2.2370	-2.5100	-2.3100	-1.1340	-1.3530
1	191	20.1100	17.7300	18.6700	3.5020	2.9030	2.9160	-2.3800	-1.4400	-0.5990	-0.5860
1	192	17.8100	18.7100	18.9600	3.6540	3.8470	3.8290	0.9000	1.1500	0.1930	0.1750
1	193	18.1200	19.9200	17.4900	4.2230	4.7380	4.2580	1.8000	-0.6300	0.5150	0.0350
1	194	16.7000	15.3500	16.2100	6.3410	5.6760	6.4410	-1.3500	-0.4900	-0.6650	0.1000
1	195	13.1900	13.4800	11.5300	5.6260	5.9400	4.8310	0.2900	-1.6600	0.3140	-0.7950
1	196	17.2800	17.7200	16.4300	5.6750	5.9690	5.4050	0.4400	-0.8500	0.2940	-0.2700
1	197	16.3100	16.8200	15.7400	5.8510	5.7840	5.1150	0.5100	-0.5700	-0.0670	-0.7360
1	198	19.5100	18.1900	16.7200	4.8690	4.2920	3.5440	-1.3200	-2.7900	-0.5770	-1.3250
1	199	13.0500	12.4400	11.2700	5.8440	5.4430	5.1440	-0.6100	-1.7800	-0.4010	-0.7000
1	200	18.7500	17.4000	15.5500	5.0130	4.4080	3.6780	-1.3500	-3.2000	-0.6050	-1.3350
1	201	16.9300	16.7400	15.7000	5.8420	5.6760	5.3000	-0.1900	-1.2300	-0.1660	-0.5420
1	202	14.9000	18.7400	19.6000	4.7410	4.3480	4.2540	3.8400	4.7000	-0.3930	-0.4870
1	203	17.2500	16.4200	15.5000	6.0420	5.6140	5.3190	-0.8300	-1.7500	-0.4280	-0.7230
1	204	17.8200	17.3100	11.6500	4.8310	4.9810	4.2540	-0.5100	-6.1700	0.1500	-0.5770
1	205	12.8500	13.8300	11.8000	5.5480	6.2450	5.1240	0.9800	-1.0500	0.6970	-0.4240
1	206	14.1300	14.9000	13.0400	4.6530	4.9710	3.9070	0.7700	-1.0900	0.3180	-0.7460
1	207	13.0200	14.8500	14.8200	4.6580	5.6410	5.2270	1.8300	1.8000	0.9830	0.5690
1	208	16.9300	18.3500	18.3500	4.1470	4.6760	4.4280	1.4200	1.4200	0.5290	0.2810
1	209	21.1200	20.1600	18.3400	4.5550	4.2370	3.7800	-0.9600	-2.7800	-0.3180	-0.7750
1	210	17.9400	18.7200	16.7900	3.7780	3.9680	3.1630	0.7800	-1.1500	0.1900	-0.6150
1	211	16.6200	16.0700	14.8400	4.2380	4.6500	4.2990	-0.5500	-1.7800	0.4120	0.0610
1	212	14.0900	14.6100	13.8900	4.5620	4.6920	4.2800	0.5200	-0.2000	0.1300	-0.2820

Figure F-4. Vendor 1 Refresh Times Measured at V_{CC}=6.0 volts (Worst-case bits)

Vendor 1 Refresh times (seconds) Measured at Vcc=7.0 volts

1000 Random bits

		Mean			Sigma			Mean delta		Sigma delta	
Cell	S/N	0 hrs	160 hrs	4000 hrs	0 hrs	160 hrs	4000 hrs	0 to 160	0 to 4000	0 to 160	0 to 4000
1	130	18.4900	18.0800	13.5800	7.0350	4.8050	6.7100	-0.41000	-4.91000	-2.23000	-0.32500
1	131	15.9000	3.2940	1.5520	7.2700	3.2520	1.6280	-12.60600	-14.34800	-4.01800	-5.64200
1	133	20.9600	18.3100	20.1300	4.9630	4.2080	4.9180	-2.65000	-0.83000	-0.75500	-0.04500
1	132	21.2600	21.8800	19.1100	5.1800	5.4320	4.8070	0.62000	-2.15000	0.25200	-0.37300
1	134	21.1800	18.6400	18.5500	5.1770	4.4990	4.6740	-2.54000	-2.63000	-0.67800	-0.50300
1	135	21.5100	18.6200	18.9900	4.2520	3.5720	3.7200	-2.89000	-2.52000	-0.68000	-0.53200
1	137	21.7600	18.4700	19.0200	5.5060	4.5040	4.9670	-3.29000	-2.74000	-1.00200	-0.53900
1	139	21.6000	18.8000	20.0900	4.8940	4.0860	4.5310	-2.80000	-1.51000	-0.80800	-0.36300
1	140	20.3400	18.5900	18.1900	4.1540	3.8020	3.7800	-1.75000	-2.15000	-0.35200	-0.37400
1	141	19.8300	19.0800	18.5300	4.1850	3.9650	3.8590	-0.75000	-1.30000	-0.22000	-0.32600
1	142	15.3400	14.6200	14.5100	6.2740	5.9400	6.0290	-0.72000	-0.83000	-0.33400	-0.24500
1	143	21.2100	19.2800	21.0300	4.8540	4.3340	5.0570	-1.93000	-0.18000	-0.52000	0.20300
1	144	20.7700	19.0800	23.1200	4.1170	3.7150	4.7800	-1.69000	2.35000	-0.40200	0.66300
1	145	23.3400	19.4300	23.4300	5.6370	4.4650	6.0840	-3.91000	0.09000	-1.17200	0.44700
1	146	20.6500	15.7300	17.8600	4.9730	3.6870	4.5920	-4.92000	-2.79000	-1.28600	-0.38100
1	147	21.2900	19.8900	21.0800	4.7430	4.3740	4.8880	-1.40000	-0.21000	-0.36900	0.14500
1	148	19.9500	19.1100	18.5700	3.9910	3.7540	3.6460	-0.84000	-1.38000	-0.23700	-0.34500
1	149	21.2100	19.9000	23.2000	4.5950	4.2680	5.2580	-1.31000	1.99000	-0.32700	0.66300
1	150	20.0200	19.1800	17.9100	4.4220	4.2160	4.0180	-0.84000	-2.11000	-0.20600	-0.40400
1	151	16.8800	15.1800	14.7000	7.2550	6.3160	6.4820	-1.70000	-2.18000	-0.93900	-0.77300
1	152	20.6300	20.2500	18.3500	4.7090	4.6120	4.2610	-0.38000	-2.28000	-0.09700	-0.44800
1	153	18.9200	19.4700	23.7200	3.9830	4.1590	5.4060	0.55000	4.80000	0.17600	1.42300
1	154	20.1200	18.9300	19.9000	4.4200	4.1620	4.4630	-1.19000	-0.22000	-0.25800	0.04300
1	155	16.2300	No test	No test	6.0700	No test	No test	No test	No test	No test	No test
1	156	15.6300	17.5800	17.4700	5.7090	6.8420	7.5770	1.95000	1.84000	1.13300	1.86800
1	157	22.0000	23.6800	21.0600	4.8310	5.3070	4.5600	1.68000	-0.94000	0.47600	-0.27100
1	158	18.3300	18.9300	19.8700	3.5500	3.7030	3.9360	0.60000	1.54000	0.15300	0.38600
1	159	20.5200	19.8300	19.4600	4.3580	4.2150	4.1400	-0.69000	-1.06000	-0.14300	-0.21800
1	160	17.9800	15.4600	14.5900	7.1620	5.7270	5.7030	-2.52000	-3.39000	-1.43500	-1.45900
1	161	20.3800	20.4400	21.8300	4.6610	4.9130	5.5810	0.06000	1.45000	0.25200	0.92000
1	162	23.9400	20.0700	23.1100	4.9830	3.9600	4.7850	-3.87000	-0.83000	-1.02300	-0.19800
1	163	22.8100	19.3400	22.4100	5.1820	4.2060	5.1570	-3.47000	-0.40000	-0.97600	-0.02500
1	164	19.6800	18.7700	21.5100	4.4980	4.3060	5.2690	-0.91000	1.83000	-0.19200	0.77100
1	165	20.9700	19.1600	21.2500	4.6770	4.2060	4.8290	-1.81000	0.28000	-0.47100	0.15200
1	166	22.1500	19.0900	20.4700	5.3420	4.5000	5.0880	-3.06000	-1.68000	-0.84200	-0.25400
1	167	16.6000	14.3100	13.8600	7.2330	5.8600	6.1770	-2.29000	-2.74000	-1.37300	-1.05600
1	168	21.3100	18.3000	19.8200	4.8300	4.1170	4.6630	-3.01000	-1.49000	-0.71300	-0.16700
1	169	18.3300	17.4000	20.0700	5.4950	5.1660	6.7720	-0.93000	1.74000	-0.32900	1.27700
1	170	21.1800	18.0200	19.2600	4.5020	3.8710	4.2960	-3.16000	-1.92000	-0.63100	-0.20600
1	171	21.9200	18.9900	15.3700	4.5220	3.7960	5.3140	-2.93000	-6.55000	-0.72600	0.79200

Figure F-5. Vendor 1 Refresh Times Measured at V_{CC}=7.0 volts (Random bits)

1	172	21.7100	19.9400	19.8800	4.8060	4.3030	4.3630	-1.77000	-1.83000	-0.50300	-0.44300
1	173	19.9500	18.4900	18.9000	4.1130	3.7440	3.8560	-1.46000	-1.05000	-0.36900	-0.25700
1	174	15.9000	14.4900	14.8500	6.4950	5.5760	6.1210	-1.41000	-1.05000	-0.91900	-0.37400
1	175	16.2800	13.8600	15.0200	6.3910	5.1090	6.4780	-2.42000	-1.26000	-1.28200	0.08700
1	176	22.0000	18.1500	18.3400	5.0420	3.9600	4.1450	-3.85000	-3.66000	-1.08200	-0.89700
1	177	20.4200	18.3900	17.8000	5.3010	4.7480	5.0230	-2.03000	-2.62000	-0.55300	-0.27800
1	178	14.7300	14.0600	13.6700	6.2920	5.8780	6.5080	-0.67000	-1.06000	-0.41400	0.21600
1	179	21.2200	22.6200	23.4900	4.5440	4.9240	5.8130	1.40000	2.27000	0.38000	1.26900
1	180	13.6500	14.6200	14.0900	6.3360	7.1900	7.8080	0.97000	0.44000	0.85400	1.47200
1	181	19.0700	18.9700	16.2600	4.5390	4.6720	4.1040	-0.10000	-2.81000	0.13300	-0.43500
1	182	23.8900	23.5300	22.3400	5.8760	6.3100	5.6260	-0.36000	-1.55000	0.43400	-0.25000
1	183	21.4900	22.1300	23.4200	4.5490	4.7720	5.1520	0.64000	1.93000	0.22300	0.60300
1	184	15.7500	15.5700	16.7500	6.3890	6.3360	7.5320	-0.18000	1.00000	-0.05300	1.14300
1	185	20.9900	20.7300	22.3500	5.4960	5.5140	6.5090	-0.26000	1.36000	0.01800	1.01300
1	186	14.6300	14.3400	13.3700	6.7500	6.8140	6.4780	-0.29000	-1.26000	0.06400	-0.27200
1	187	13.5800	13.1000	12.0100	6.7130	6.8560	6.5670	-0.48000	-1.57000	0.14300	-0.14600
1	189	19.8300	19.5900	20.4400	4.1280	4.1090	4.2640	-0.24000	0.61000	-0.01900	0.13600
1	190	21.6100	20.5900	20.7000	4.4460	4.2060	4.1350	-1.02000	-0.91000	-0.24000	-0.31100
1	191	21.0900	21.1900	22.2300	5.4710	4.3160	4.5580	0.10000	1.14000	-1.15500	-0.91300
1	192	19.2500	20.2600	20.3400	4.5170	4.8340	4.9810	1.01000	1.09000	0.31700	0.46400
1	193	19.6200	21.5000	13.4000	4.6810	5.3770	8.4260	1.88000	-6.22000	0.69600	3.74500
1	194	21.2200	19.4000	20.6000	5.6510	5.1130	5.8920	-1.82000	-0.62000	-0.53800	0.24100
1	195	14.4400	14.4800	12.2900	6.6010	7.1540	6.1050	0.04000	-2.15000	0.55300	-0.49600
1	196	20.8300	21.6400	19.8700	5.1570	5.4680	5.1130	0.81000	-0.96000	0.31100	-0.04400
1	197	21.2100	21.6900	19.9400	5.1250	5.2960	4.8580	0.48000	-1.27000	0.17100	-0.26700
1	198	22.7000	20.9700	18.9600	4.8430	4.3610	3.8670	-1.73000	-3.74000	-0.48200	-0.97600
1	199	13.3700	12.4700	11.0500	6.7370	6.4740	6.2450	-0.90000	-2.32000	-0.26300	-0.49200
1	200	18.0700	16.7800	15.0400	6.9750	6.3200	5.5020	-1.29000	-3.03000	-0.65500	-1.47300
1	201	21.4800	21.2600	19.7900	5.3480	5.3490	5.0600	-0.22000	-1.69000	0.00100	-0.28800
1	202	13.9700	20.7400	21.4000	6.7290	4.5880	4.6320	6.77000	7.43000	-2.14100	-2.09700
1	203	22.3300	20.9700	19.6400	5.4430	5.1060	4.9210	-1.36000	-2.69000	-0.33700	-0.52200
1	204	18.1100	16.2800	7.4800	6.1450	6.8610	5.7830	-1.83000	-10.63000	0.71600	-0.36200
1	205	15.0600	15.9400	13.3100	6.2090	7.0810	6.0710	0.88000	-1.75000	0.87200	-0.13800
1	206	18.8100	18.8800	15.9100	4.0760	4.3600	3.6940	0.07000	-2.90000	0.28400	-0.38200
1	207	15.3000	17.2700	16.5800	5.3880	6.6450	6.7020	1.97000	1.28000	1.25700	1.31400
1	208	19.4800	21.0000	20.7400	4.0680	4.5060	4.5210	1.52000	1.26000	0.43800	0.45300
1	209	22.5400	21.4700	19.5200	4.6140	4.3700	3.9180	-1.07000	-3.02000	-0.24400	-0.69600
1	210	19.4700	20.3400	12.2100	3.8220	4.0540	6.7450	0.87000	-7.26000	0.23200	2.92300
1	211	21.7900	19.7800	17.5600	4.9980	6.2900	6.1830	-2.01000	-4.23000	1.29200	1.18500
1	212	15.6300	15.7600	14.9300	6.6800	7.2210	6.7450	0.13000	-0.70000	0.54100	0.06500

Figure F-5. Vendor 1 Refresh Times Measured at V_{CC}=7.0 volts (Random bits)

Vendor 1 Refresh times (seconds) Measured at Vcc=7.0 volts

1000 Worst case bits

		Mean			Sigma			Mean delta		Sigma delta	
Cell	S/N	0 hrs	160 hrs	4000 hrs	0 hrs	160 hrs	4000 hrs	0 to 160	0 to 4000	0 to 160	0 to 4000
1	130	9.6930	8.0880	2.8310	6.1110	5.2700	2.2160	-1.60500	-6.86200	-0.84100	-3.89500
1	131	3.1660	0.3017	0.1492	2.8650	0.4484	0.2183	-2.86430	-3.01680	-2.41660	-2.64670
1	133	12.9400	11.3500	12.2800	5.8800	5.0840	5.7360	-1.59000	-0.66000	-0.79600	-0.14400
1	132	10.6900	10.9500	9.5230	6.6110	6.8740	6.0620	0.26000	-1.16700	0.26300	-0.54900
1	134	10.4100	9.2160	8.9420	6.4700	5.6580	5.6710	-1.19400	-1.46800	-0.81200	-0.79900
1	135	15.2600	13.2600	13.5500	4.2860	3.6190	3.6860	-2.00000	-1.71000	-0.66700	-0.60000
1	137	10.3200	8.8850	8.9080	6.7180	5.6590	5.9650	-1.43500	-1.41200	-1.05900	-0.75300
1	139	13.0800	11.4500	12.1100	5.7110	4.8890	5.2350	-1.63000	-0.97000	-0.82200	-0.47600
1	140	14.2800	13.0400	12.7500	4.1280	3.7480	3.7030	-1.24000	-1.53000	-0.38000	-0.42500
1	141	14.0000	13.4600	13.0300	4.3120	4.1190	3.9920	-0.54000	-0.97000	-0.19300	-0.32000
1	142	7.0040	6.6730	6.4790	3.0700	2.9260	2.8690	-0.33100	-0.52500	-0.14400	-0.20100
1	143	11.8400	10.8200	11.5400	6.0130	5.4200	6.0470	-1.02000	-0.30000	-0.59300	0.03400
1	144	17.5200	16.0200	19.4100	4.3050	3.8710	4.9090	-1.50000	1.89000	-0.43400	0.60400
1	145	12.9300	10.9500	12.6600	7.2130	5.9110	7.4630	-1.98000	-0.27000	-1.30200	0.25000
1	146	11.1800	8.6950	9.5060	6.0350	4.5650	5.2830	-2.48500	-1.67400	-1.47000	-0.75200
1	147	14.4900	13.5000	14.1300	4.9300	4.5300	4.9390	-0.99000	-0.36000	-0.40000	0.00900
1	148	17.0700	16.2700	15.7500	3.9240	3.6930	3.4920	-0.80000	-1.32000	-0.23100	-0.43200
1	149	12.6200	11.8500	13.6100	5.8170	5.3760	6.4080	-0.77000	0.99000	-0.44100	0.59100
1	150	12.7300	12.2300	11.3400	5.4870	5.2160	4.9620	-0.50000	-1.39000	-0.27100	-0.52500
1	151	6.3460	5.8600	5.3350	3.4890	3.1530	2.9590	-0.48600	-1.01100	-0.33600	-0.53000
1	152	12.5200	12.2900	11.0700	5.6370	5.5330	5.0740	-0.23000	-1.45000	-0.10400	-0.56300
1	153	12.2700	12.5600	15.0400	5.0110	5.1520	6.4320	0.29000	2.77000	0.14100	1.42100
1	154	12.9500	12.1600	12.6900	5.2290	4.8940	5.1440	-0.79000	-0.26000	-0.33500	-0.08500
1	155	6.3780	No test	No test	3.2250	No test	No test	No test	No test	No test	No test
1	156	6.7270	7.1330	6.7860	2.5380	2.8400	2.8460	0.40600	0.05900	0.30200	0.30800
1	157	14.2400	15.2300	13.6600	5.1660	5.6100	4.8220	0.99000	-0.58000	0.44400	-0.34400
1	158	13.2300	13.6100	14.2400	3.5790	3.7100	3.8730	0.38000	1.01000	0.13100	0.29400
1	159	13.4200	12.9000	12.6000	4.7040	4.4930	4.3370	-0.52000	-0.82000	-0.21100	-0.36700
1	160	6.2070	5.6280	5.0410	3.6080	3.1090	2.8530	-0.57900	-1.16600	-0.49900	-0.75500
1	161	12.1900	11.9300	12.3800	5.5390	5.5560	5.9720	-0.26000	0.19000	0.01700	0.43300
1	162	16.1900	13.7300	15.6400	5.6360	4.5980	5.3760	-2.46000	-0.55000	-1.03800	-0.26000
1	163	14.9400	12.8100	14.5900	5.9480	4.9200	5.8070	-2.13000	-0.35000	-1.02800	-0.14100
1	164	11.0600	10.4800	11.6400	5.4130	5.0990	5.9340	-0.58000	0.58000	-0.31400	0.52100
1	165	12.1800	11.1700	12.2400	5.9100	5.3540	5.9780	-1.01000	0.06000	-0.55600	0.06800
1	166	11.6400	10.1400	10.6700	6.4790	5.5260	6.0080	-1.50000	-0.97000	-0.95300	-0.47100
1	167	5.0640	4.6900	4.1130	2.9600	2.5740	2.3990	-0.37400	-0.95100	-0.38600	-0.56100
1	168	13.0300	11.1900	11.9300	5.9150	4.9850	5.3910	-1.84000	-1.10000	-0.93000	-0.52400
1	169	7.9430	7.5460	7.8980	4.9140	4.6730	5.2530	-0.39700	-0.04500	-0.24100	0.33900
1	170	13.8800	11.9700	12.6900	5.1040	4.4240	4.7980	-1.91000	-1.19000	-0.68000	-0.30600
1	171	15.4600	13.4900	9.8930	4.3350	3.6760	4.3520	-1.97000	-5.56700	-0.65900	0.01700

Figure F-6. Vendor 1 Refresh Times Measured at V_{CC}=7.0 volts (Worst-case bits)

1	172	14.1000	12.9900	12.9300	5.0410	4.5530	4.5430	-1.11000	-1.17000	-0.48800	-0.49800
1	173	14.0300	13.0400	13.2600	4.1730	3.8130	3.8560	-0.99000	-0.77000	-0.36000	-0.31700
1	174	5.5240	5.3750	5.0670	2.8930	2.6880	2.6090	-0.14900	-0.45700	-0.20500	-0.28400
1	175	5.9630	5.4030	4.9460	2.9290	2.4980	2.5460	-0.56000	-1.01700	-0.43100	-0.38300
1	176	12.6800	10.6000	10.5700	6.0660	4.9210	5.0130	-2.08000	-2.11000	-1.14500	-1.05300
1	177	9.7330	8.7670	8.0840	6.2000	5.5900	5.5590	-0.96600	-1.64900	-0.61000	-0.64100
1	178	3.0610	3.0020	2.4950	2.6830	2.5830	2.3240	-0.05900	-0.56600	-0.10000	-0.35900
1	179	13.7700	14.5800	13.3300	5.6250	6.0090	7.4150	0.81000	-0.44000	0.38400	1.79000
1	180	3.0080	2.9990	2.4730	2.4280	2.5340	2.3110	-0.00900	-0.53500	0.10600	-0.11700
1	181	10.0700	9.8440	8.3540	5.8780	5.7920	4.9800	-0.22600	-1.71600	-0.08600	-0.89800
1	182	11.5300	9.6250	10.7000	7.1440	6.9460	6.7000	-1.90500	-0.83000	-0.19800	-0.44400
1	183	14.2300	14.5500	15.2500	5.4530	5.6440	5.9060	0.32000	1.02000	0.19100	0.45300
1	184	4.9480	4.8520	4.7000	3.2300	3.1720	3.2690	-0.09600	-0.24800	-0.05800	0.03900
1	185	9.7090	9.5470	9.7960	6.6770	6.6510	7.3230	-0.16200	0.08700	-0.02600	0.64600
1	186	4.1410	3.9210	3.5980	2.5770	2.4810	2.2960	-0.22000	-0.54300	-0.09600	-0.28100
1	187	2.3040	2.0700	1.7920	2.1330	1.9960	1.7580	-0.23400	-0.51200	-0.13700	-0.37500
1	189	14.3000	14.0900	14.6300	4.3600	4.2950	4.4230	-0.21000	0.33000	-0.06500	0.06300
1	190	16.3000	14.5800	14.6300	5.4010	4.0400	3.9170	-1.72000	-1.67000	-1.36100	-1.48400
1	191	16.2100	14.6200	15.3100	5.2630	4.6110	4.7770	-1.59000	-0.90000	-0.65200	-0.48600
1	192	14.5200	15.1500	15.1600	5.0410	5.3310	5.4030	0.63000	0.64000	0.29000	0.36200
1	193	14.6900	16.0100	9.3900	5.7370	6.4580	6.7370	1.32000	-5.30000	0.72100	1.00000
1	194	10.8900	9.9160	10.1400	7.9320	7.1890	7.8390	-0.97400	-0.75000	-0.74300	-0.09300
1	195	3.8430	3.5300	3.0040	3.5520	3.5350	2.9740	-0.31300	-0.83900	-0.01700	-0.57800
1	196	12.2100	12.5800	11.4300	7.4010	7.7370	7.1040	0.37000	-0.78000	0.33600	-0.29700
1	197	11.4400	11.6500	10.7100	7.5740	7.7850	7.0800	0.21000	-0.73000	0.21100	-0.49400
1	198	14.3000	13.2500	12.0200	7.0780	6.4620	5.6820	-1.05000	-2.28000	-0.61600	-1.39600
1	199	3.3680	3.0440	2.4400	3.2500	3.0200	2.6320	-0.32400	-0.92800	-0.23000	-0.61800
1	200	7.9930	7.5300	6.7520	4.3660	4.0680	3.5340	-0.46300	-1.24100	-0.29800	-0.83200
1	201	11.6300	11.4400	10.5400	7.4020	7.3090	6.8250	-0.19000	-1.09000	-0.09300	-0.57700
1	202	3.8570	14.1700	14.8200	2.5530	6.3050	6.4170	10.31300	10.96300	3.75200	3.86400
1	203	11.6100	10.9000	9.7700	7.6800	7.1880	6.5060	-0.71000	-1.84000	-0.49200	-1.17400
1	204	9.6420	6.4120	1.8760	5.0820	4.0850	2.0770	-3.23000	-7.76600	-0.99700	-3.00500
1	205	4.4640	4.3730	3.5510	3.8160	3.9240	3.1460	-0.09100	-0.91300	0.10800	-0.67000
1	206	8.6200	8.5670	7.2850	6.1790	6.4300	5.3520	-0.05300	-1.33500	0.25100	-0.82700
1	207	5.0160	5.1880	4.6780	3.7730	4.1110	3.7260	0.17200	-0.33800	0.33800	-0.04700
1	208	12.8900	13.7700	13.4800	6.0610	6.6090	6.4820	0.88000	0.59000	0.54800	0.42100
1	209	17.2300	16.4500	14.8700	6.4890	6.1470	5.3780	-0.78000	-2.36000	-0.34200	-1.11100
1	210	13.8900	14.4400	9.2320	5.5820	5.8840	5.3900	0.55000	-4.65800	0.30200	-0.19200
1	211	12.6200	8.6960	6.9820	6.1130	5.0910	4.3220	-3.92400	-5.63800	-1.02200	-1.79100
1	212	4.7210	4.3990	4.2790	2.9390	2.8760	2.7360	-0.32200	-0.44200	-0.06300	-0.20300

Figure F-6. Vendor 1 Refresh Times Measured at V_{CC}=7.0 volts (Worst-case bits)

Vendor 2 Refresh times (seconds) Measured at Vcc=5.5 volts

1000 Random bits

		Mean			Sigma			Mean delta		Sigma delta	
Cell	S/N	0 hrs	160 hrs	4000 hrs	0 hrs	160 hrs	4000 hrs	0 to 160	0 to 4000	0 to 160	0 to 4000
3	329	0.83500	0.85800	0.85550	0.39630	0.40400	0.34170	0.02300	0.02050	0.00770	-0.05460
2	330	0.83890	0.78970	0.84100	0.39670	0.37990	0.34660	-0.04920	0.00210	-0.01680	-0.05010
3	331	0.67270	0.74640	0.86620	0.35060	0.38200	0.35390	0.07370	0.19350	0.03140	0.00330
3	332	0.91190	0.84840	0.89210	0.40030	0.35540	0.36160	-0.06350	-0.01980	-0.04490	-0.03870
3	333	0.86840	0.78760	0.81710	0.39550	0.38080	0.34890	-0.08080	-0.05130	-0.01470	-0.04660
3	334	0.90430	0.87400	0.82350	0.39080	0.39230	0.33140	-0.03030	-0.08080	0.00150	-0.05940
3	335	0.94550	0.83310	0.85080	0.41170	0.37180	0.33600	-0.11240	-0.09470	-0.03990	-0.07570
3	337	0.68060	0.75300	0.64930	0.34330	0.37280	0.27490	0.07240	-0.03130	0.02950	-0.06840
3	338	0.99700	0.83830	No test	0.42670	0.37360	No test	-0.15870	No test	-0.05310	No test
3	339	1.01600	1.01300	0.98940	0.44220	0.44050	0.39750	-0.00300	-0.02660	-0.00170	-0.04470
3	340	1.01700	0.94210	0.86760	0.42450	0.41940	0.35240	-0.07490	-0.14940	-0.00510	-0.07210
3	341	1.03000	0.88980	0.91130	0.45590	0.41340	0.36750	-0.14020	-0.11870	-0.04250	-0.08840
3	342	0.61700	0.83640	0.84420	0.39300	0.37930	0.33670	0.21940	0.22720	-0.01370	-0.05630
2	343	1.02800	1.00000	0.88390	0.42360	0.41960	0.35830	-0.02800	-0.14410	-0.00400	-0.06530
3	344	1.00000	0.91020	0.82330	0.41690	0.40510	0.34290	-0.08980	-0.17670	-0.01180	-0.07400
3	345	0.93210	0.81180	0.79960	0.42030	0.37970	0.33990	-0.12030	-0.13250	-0.04060	-0.08040
3	346	0.82020	0.74890	0.58070	0.37880	0.37530	0.25150	-0.07130	-0.23950	-0.00350	-0.12730
3	347	1.06800	0.99030	0.40060	0.42370	0.42100	0.37330	-0.07770	-0.66740	-0.00270	-0.05040
3	348	1.06700	1.07600	1.06500	0.42600	0.42000	0.37210	0.00900	-0.00200	-0.00600	-0.05390
3	349	0.81890	0.82860	0.85160	0.40420	0.40640	0.36440	0.00970	0.03270	0.00220	-0.03980
2	350	0.70670	0.76640	0.60500	0.36540	0.39660	0.25560	0.05970	-0.10170	0.03120	-0.10980
3	351	0.81330	0.80640	0.65840	0.36880	0.38600	0.27430	-0.00690	-0.15490	0.01720	-0.09450
3	352	0.81950	0.80030	0.68920	0.38800	0.37740	0.29080	-0.01920	-0.13030	-0.01060	-0.09720
3	353	0.94850	0.80340	0.70480	0.40770	0.36110	0.30320	-0.14510	-0.24370	-0.04660	-0.10450
3	354	0.84500	0.86940	0.19190	0.35410	0.37060	0.36320	0.02440	-0.65310	0.01650	0.00910
2	355	0.54480	0.78670	0.64670	0.37910	0.39270	0.27820	0.24190	0.10190	0.01360	-0.10090
3	356	0.73160	0.75480	0.38850	0.39240	0.40790	0.19420	0.02320	-0.34310	0.01550	-0.19820
3	357	0.87570	0.77120	0.89330	0.40920	0.38230	0.39090	-0.10450	0.01760	-0.02690	-0.01830
3	358	0.92650	0.82250	0.47400	0.41610	0.36180	0.17290	-0.10400	-0.45250	-0.05430	-0.24320
3	359	0.76650	0.60000	0.66170	0.36150	0.29820	0.30810	-0.16650	-0.10480	-0.06330	-0.05340
2	360	0.94190	1.13700	1.06500	0.54350	0.49030	0.37770	0.19510	0.12310	-0.05320	-0.16580
2	361	0.83640	0.88780	0.81910	0.36820	0.39130	0.34510	0.05140	-0.01730	0.02310	-0.02310
3	362	0.82220	0.81660	0.36990	0.38380	0.38240	0.23500	-0.00560	-0.45230	-0.00140	-0.14880
3	363	0.60680	0.67510	0.79930	0.30450	0.34710	0.37030	0.06830	0.19250	0.04260	0.06580
2	364	0.04028	0.61160	0.57920	0.01045	0.30500	0.24710	0.57132	0.53892	0.29455	0.23665
2	365	0.05483	0.70610	0.65200	0.05219	0.35510	0.28690	0.65127	0.59717	0.30291	0.23471
2	366	0.63250	0.82110	0.83480	0.44470	0.35750	0.34690	0.18860	0.20230	-0.08720	-0.09780
2	367	0.06961	0.61150	0.59230	0.02692	0.29950	0.25450	0.54189	0.52269	0.27258	0.22758
2	368	0.07554	0.56470	0.57960	0.01881	0.28130	0.24700	0.48916	0.50406	0.26249	0.22819
2	369	1.17800	0.90050	1.13100	0.47820	0.39720	0.34890	-0.27750	-0.04700	-0.08100	-0.12930

Figure F-7. Vendor 2 Refresh Times Measured at V_{CC}=5.5 volts (Random bits)

2	370	0.62220	0.61470	0.66010	0.36550	0.29680	0.27770	-0.00750	0.03790	-0.06870	-0.08780
2	371	0.81030	0.65540	0.70600	0.36180	0.31750	0.31070	-0.15490	-0.10430	-0.04430	-0.05110
2	372	0.19250	0.58290	0.54060	0.09051	0.28300	0.23900	0.39040	0.34810	0.19249	0.14849
2	373	0.84220	0.82130	0.85740	0.58320	0.37510	0.35420	-0.02090	0.01520	-0.20810	-0.22900
2	374	0.48100	0.53290	0.54140	0.20750	0.25760	0.25140	0.05190	0.06040	0.05010	0.04390
2	375	0.49860	0.90810	0.98780	0.54930	0.40450	0.38010	0.40950	0.48920	-0.14480	-0.16920
3	376	0.96230	0.82280	0.99860	0.40720	0.36720	0.38410	-0.13950	0.03630	-0.04000	-0.02310
3	377	1.02800	0.91620	1.05000	0.40750	0.40060	0.38710	-0.11180	0.02200	-0.00690	-0.02040
3	378	1.04300	0.92740	1.14600	0.40960	0.40060	0.39940	-0.11560	0.10300	-0.00900	-0.01020
3	379	1.01700	0.91570	1.00700	0.40880	0.41780	0.40500	-0.10130	-0.01000	0.00900	-0.00380
2	380	0.88560	0.69720	0.83670	0.40110	0.33680	0.35170	-0.18840	-0.04890	-0.06430	-0.04940
2	381	0.77600	0.59120	0.66600	0.40890	0.27360	0.27940	-0.18480	-0.11000	-0.13530	-0.12950
2	382	1.11700	0.88190	1.01700	0.47050	0.38730	0.38710	-0.23510	-0.10000	-0.08320	-0.08340
2	383	1.12800	0.86390	0.88770	0.43120	0.38370	0.34910	-0.26410	-0.24030	-0.04750	-0.08210
2	384	0.73950	0.56630	0.65720	0.38140	0.28090	0.28940	-0.17320	-0.08230	-0.10050	-0.09200
2	385	0.81420	0.62500	0.74000	0.39140	0.29190	0.31660	-0.18920	-0.07420	-0.09950	-0.07480
2	386	0.94250	0.80310	0.83540	0.42670	0.38950	0.36050	-0.13940	-0.10710	-0.03720	-0.06620
2	387	0.87520	0.75760	0.86240	0.38990	0.36680	0.36470	-0.11760	-0.01280	-0.02310	-0.02520
2	388	0.85490	0.77030	0.96620	0.37960	0.37600	0.37020	-0.08460	0.11130	-0.00360	-0.00940
2	389	1.03700	0.88180	1.01900	0.44560	0.39540	0.39020	-0.15520	-0.01800	-0.05020	-0.05540
2	390	0.77580	0.71020	0.80150	0.36480	0.33780	0.33790	-0.06560	0.02570	-0.02700	-0.02690
2	391	0.54600	0.52870	0.58350	0.25640	0.25090	0.24180	-0.01730	0.03750	-0.00550	-0.01460
2	392	0.92850	0.74590	0.78020	0.37820	0.36820	0.33380	-0.18260	-0.14830	-0.01000	-0.04440
2	393	0.95620	0.83180	0.90180	0.40090	0.37000	0.34930	-0.12440	-0.05440	-0.03090	-0.05160
2	394	0.56510	0.48930	0.54600	0.27450	0.23480	0.23420	-0.07580	-0.01910	-0.03970	-0.04030
2	395	0.52740	0.48710	0.56280	0.26380	0.24950	0.25830	-0.04030	0.03540	-0.01430	-0.00550
2	396	0.84750	0.79650	0.87220	0.36780	0.36990	0.35370	-0.05100	0.02470	0.00210	-0.01410
2	397	0.95740	0.80610	0.91410	0.43270	0.38050	0.36560	-0.15130	-0.04330	-0.05220	-0.06710
2	398	0.85440	0.74780	0.86620	0.36340	0.34760	0.34500	-0.10660	0.01180	-0.01580	-0.01840
2	399	1.09100	0.86740	1.01700	0.43410	0.39940	0.40270	-0.22360	-0.07400	-0.03470	-0.03140
2	400	1.30300	1.11300	1.27200	0.44310	0.43050	0.39350	-0.19000	-0.03100	-0.01260	-0.04960
2	401	0.59750	0.52780	0.64260	0.29720	0.25370	0.27240	-0.06970	0.04510	-0.04350	-0.02480
2	402	0.91670	0.77340	0.85990	0.40980	0.37280	0.35830	-0.14330	-0.05680	-0.03700	-0.05150
2	403	0.84250	0.80060	0.85760	0.39800	0.38110	0.35030	-0.04190	0.01510	-0.01690	-0.04770
2	404	0.77490	0.62870	0.73860	0.37980	0.29910	0.31770	-0.14620	-0.03630	-0.08070	-0.06210
2	405	0.79270	0.59310	0.68270	0.36050	0.28800	0.29130	-0.19960	-0.11000	-0.07250	-0.06920
2	407	1.13900	1.03900	1.14500	0.42520	0.42010	0.40700	-0.10000	0.00600	-0.00510	-0.01820
2	408	0.75300	0.55960	0.82510	0.37040	0.26200	0.35290	-0.19340	0.07210	-0.10840	-0.01750
2	409	0.82590	0.66630	0.76070	0.37420	0.30560	0.31780	-0.15960	-0.06520	-0.06860	-0.05640
2	410	0.78250	0.78750	1.12300	0.38870	0.38900	0.42050	0.00500	0.34050	0.00030	0.03180
2	411	0.98240	0.83880	0.91950	0.44590	0.40640	0.38990	-0.14360	-0.06290	-0.03950	-0.05600
2	413	0.81380	0.65940	0.82000	0.39700	0.35980	0.35210	-0.15440	0.00620	-0.03720	-0.04490
2	414	0.62740	0.53600	0.60320	0.32060	0.27240	0.25990	-0.09140	-0.02420	-0.04820	-0.06070
2	415	0.87780	0.78530	0.85940	0.39840	0.37630	0.35450	-0.09250	-0.01840	-0.02210	-0.04390

Figure F-7. Vendor 2 Refresh Times Measured at V_{CC}=5.5 volts (Random bits)

2	416	0.95930	0.79480	0.84400	0.42640	0.37170	0.34030	-0.16450	-0.11530	-0.05470	-0.08610
2	417	1.05600	0.89070	1.05000	0.44240	0.42670	0.41870	-0.16530	-0.00600	-0.01570	-0.02370
2	418	0.71210	0.56110	0.64770	0.36090	0.26910	0.27700	-0.15100	-0.06440	-0.09180	-0.08390
2	419	0.91680	0.81080	0.86770	0.41280	0.38160	0.36040	-0.10600	-0.04910	-0.03120	-0.05240
2	420	0.82030	0.79540	0.73210	0.36940	0.39000	0.32810	-0.02490	-0.08820	0.02060	-0.04130
2	421	0.81390	0.68340	0.82820	0.37900	0.31760	0.34050	-0.13050	0.01430	-0.06140	-0.03850
2	422	0.68700	0.55050	0.60770	0.34430	0.26230	0.25770	-0.13650	-0.07930	-0.08200	-0.08660
2	423	0.70240	0.56030	0.62680	0.37040	0.27300	0.28000	-0.14210	-0.07560	-0.09740	-0.09040
2	424	1.03500	0.81470	0.99070	0.40900	0.36840	0.38630	-0.22030	-0.04430	-0.04060	-0.02270
2	425	0.33950	0.74790	0.86660	0.39530	0.36440	0.35810	-0.14170	-0.02290	-0.03090	-0.03720
2	426	0.70520	0.55800	0.67000	0.36400	0.27160	0.30960	0.14720	-0.03520	-0.09240	-0.05440
2	427	0.77210	0.65120	0.87410	0.37900	0.32010	0.36610	-0.12090	0.10200	-0.05890	-0.01290
2	428	0.66480	0.51840	0.61160	0.32680	0.24090	0.25670	-0.14640	-0.05320	-0.08590	-0.07010
2	429	0.90730	0.88550	1.03500	0.38910	0.40260	0.37720	-0.02180	0.12770	0.01350	-0.01190
2	430	0.82060	0.80110	0.92810	0.38970	0.38060	0.38740	-0.01950	0.10750	-0.00910	-0.00230
2	431	1.07600	0.88080	1.05000	0.41910	0.39230	0.40570	-0.19520	-0.02600	-0.02680	-0.01340
2	432	0.55090	0.48820	0.55580	0.27520	0.24780	0.25040	-0.06270	0.00490	-0.02740	-0.02480
2	433	0.94240	0.82920	0.95410	0.41390	0.37360	0.37290	-0.11320	0.01170	-0.04030	-0.04100
2	434	0.59510	0.45710	0.56840	0.29450	0.24940	0.24730	-0.13800	-0.02670	-0.04510	-0.04720
2	435	0.79500	0.56560	0.77200	0.37170	0.25350	0.32260	-0.22940	-0.02300	-0.11820	-0.04910
2	436	0.57600	0.49360	0.58060	0.28530	0.24250	0.25840	-0.08240	0.00460	-0.04280	-0.02690
2	437	0.65000	0.52430	0.56420	0.31530	0.24270	0.23620	-0.12570	-0.08580	-0.07260	-0.07910
2	438	0.70330	0.51180	0.60180	0.36690	0.25290	0.25730	-0.19150	-0.10150	-0.11400	-0.10960
2	439	1.02900	0.88990	0.96750	0.45140	0.41070	0.37610	-0.13910	-0.06150	-0.04070	-0.07530
2	440	0.85860	0.77450	0.85520	0.38490	0.37590	0.35900	-0.08410	-0.00340	-0.00900	-0.02590
2	441	0.87820	0.81000	0.94730	0.39130	0.38340	0.38710	-0.06820	0.06910	-0.00790	-0.00420
2	442	0.81540	0.63290	0.76780	0.37470	0.31980	0.34180	-0.18250	-0.04760	-0.05490	-0.03290

Figure F-7. Vendor 2 Refresh Times Measured at V_{CC}=5.5 volts (Random bits)

Vendor 2 Refresh times (seconds) Measured at Vcc=5.5 volts

1000 Worst case bits

		Mean			Sigma			Mean delta		Sigma delta	
Cell	S/N	0 hrs	160 hrs	4000 hrs	0 hrs	160 hrs	4000 hrs	0 to 160	0 to 4000	0 to 160	0 to 4000
3	329	0.31400	0.34920	0.41520	0.16500	0.15010	0.14190	0.03520	0.10120	-0.01490	-0.02310
2	330	0.23140	0.24240	0.32130	0.08411	0.06348	0.06919	0.01100	0.08990	-0.02063	-0.01492
3	331	0.20010	0.22530	0.36350	0.07000	0.06332	0.05323	0.02520	0.16340	-0.00668	-0.01677
3	332	0.35010	0.34780	0.40870	0.23740	0.21290	0.22530	-0.00230	0.05860	-0.02450	-0.01210
3	333	0.35010	0.29110	0.34440	0.08806	0.09058	0.09767	-0.05900	-0.00570	0.00252	0.00961
3	334	0.32270	0.33160	0.33670	0.21110	0.19180	0.18100	0.00890	0.01400	-0.01930	-0.03010
3	335	0.40450	0.31650	0.35380	0.23600	0.19840	0.19710	-0.08800	-0.05070	-0.03760	-0.03890
3	337	0.19630	0.22500	0.24340	0.06687	0.06605	0.05836	0.02870	0.04710	-0.00082	-0.00851
3	338	0.36570	0.33290	No test	0.23530	0.18570	No test	-0.03280	No test	-0.04960	No test
3	339	0.46660	0.47700	0.51620	0.37310	0.35160	0.35780	0.01040	0.04960	-0.02150	-0.01530
3	340	0.28700	0.28840	0.31630	0.10870	0.09687	0.10950	0.00140	0.02930	-0.01183	0.00080
3	341	0.42100	0.38140	0.42640	0.06496	0.04865	0.05260	-0.03960	0.00540	-0.01631	-0.01236
3	342	0.25350	0.30280	0.32530	0.09083	0.14930	0.15300	0.04930	0.07180	0.05847	0.06217
2	343	0.37880	0.38780	0.40470	0.13840	0.11010	0.09186	0.00900	0.02590	-0.02830	-0.04654
3	344	0.42470	0.40510	0.38830	0.36220	0.31040	0.28470	-0.01960	-0.03640	-0.05180	-0.07750
3	345	0.26910	0.25580	0.27270	0.12500	0.10020	0.10080	-0.01330	0.00360	-0.02480	-0.02420
3	346	0.35190	0.32110	0.30680	0.20390	0.16240	0.14750	-0.03080	-0.04510	-0.04150	-0.05640
3	347	0.39280	0.37220	0.40010	0.24890	0.18130	0.20320	-0.02060	0.00730	-0.06760	-0.04570
3	348	0.40380	0.42890	0.45160	0.32990	0.32200	0.31340	0.02510	0.04780	-0.00790	-0.01650
3	349	0.24850	0.26480	0.31600	0.08943	0.09427	0.09378	0.01630	0.06750	0.00484	0.00435
2	350	0.22980	0.24640	0.25200	0.07227	0.07120	0.06132	0.01660	0.02220	-0.00107	-0.01095
3	351	0.31600	0.31980	0.31630	0.23380	0.22170	0.20350	0.00380	0.00030	-0.01210	-0.03030
3	352	0.29540	0.29580	0.30630	0.17650	0.15600	0.15510	0.00040	0.01090	-0.02050	-0.02140
3	353	0.31620	0.28510	0.29420	0.19330	0.15320	0.14320	-0.03110	-0.02200	-0.04010	-0.05010
3	354	0.29750	0.32120	0.32940	0.19950	0.19930	0.19440	0.02370	0.03190	-0.00020	-0.00510
2	355	0.30170	0.34110	0.34910	0.05143	0.05011	0.04511	0.03940	0.04740	-0.00132	-0.00632
3	356	0.25640	0.26580	0.28480	0.07681	0.06965	0.06464	0.00940	0.02840	-0.00716	-0.01217
3	357	0.27290	0.23720	0.25460	0.09781	0.07567	0.11090	-0.03570	-0.01830	-0.02214	0.01309
3	358	0.25370	0.23980	0.26630	0.09195	0.08200	0.07834	-0.01390	0.01260	-0.00995	-0.01361
3	359	0.26970	0.24400	0.25360	0.18180	0.15200	0.17950	-0.02570	-0.01610	-0.02980	-0.00230
2	360	0.47040	0.46580	0.48670	0.39920	0.36190	0.34970	-0.00460	0.01630	-0.03730	-0.04950
2	361	0.24760	0.27300	0.27780	0.09081	0.09240	0.08539	0.02540	0.03020	0.00159	-0.00542
3	362	0.32400	0.33090	0.41570	0.24070	0.23340	0.28670	0.00690	0.09170	-0.00730	0.04600
3	363	0.27060	0.29200	0.33050	0.19050	0.19820	0.24990	0.02140	0.05990	0.00770	0.05940
2	364	0.05316	0.29310	0.30690	0.01590	0.03771	0.06232	0.23994	0.25374	0.02181	0.04642
2	365	0.03904	0.21220	0.22750	0.02671	0.06611	0.06431	0.17316	0.18846	0.03940	0.03760
2	366	0.17380	0.24010	0.25510	0.11710	0.08045	0.08474	0.06630	0.08130	-0.03665	-0.03236
2	367	0.07932	0.24680	0.26640	0.03423	0.12370	0.13380	0.16748	0.18708	0.08947	0.09957
2	368	0.08379	0.21000	0.23790	0.01769	0.09504	0.10660	0.12621	0.15411	0.07735	0.08891
2	369	0.41240	0.32130	0.45100	0.30620	0.18640	0.29010	-0.09110	0.03860	-0.11980	-0.01610

Figure F-8. Vendor 2 Refresh Times Measured at V_{CC}=5.5 volts (Worst-case bits)

2	370	0.27700	0.25390	0.29720	0.12700	0.15180	0.17110	-0.02310	0.02020	0.02480	0.04410
2	371	0.35110	0.31220	0.36020	0.26500	0.21880	0.24310	-0.03890	0.00910	-0.04620	-0.02190
2	372	0.11570	0.28300	0.28570	0.03119	0.18330	0.17510	0.16730	0.17000	0.15211	0.14391
2	373	0.38970	0.33670	0.38340	0.21430	0.16090	0.17580	-0.05300	-0.00630	-0.05340	-0.03850
2	374	0.21920	0.23010	0.26270	0.08617	0.10850	0.11870	0.01090	0.04350	0.02233	0.03253
2	375	0.18630	0.40090	0.46450	0.16860	0.09061	0.10850	0.21460	0.27820	-0.07799	-0.06010
3	376	0.29430	0.26500	0.27720	0.11070	0.09420	0.11990	-0.02930	-0.01710	-0.01650	0.00920
3	377	0.33720	0.24750	0.38380	0.12070	0.11570	0.11640	-0.08970	0.04660	-0.00500	-0.00430
3	378	0.32370	0.23170	0.31950	0.11130	0.10090	0.12610	-0.09200	-0.00420	-0.01040	0.01480
3	379	0.31080	0.29830	0.35100	0.10400	0.08752	0.09674	-0.01250	0.04020	-0.01648	-0.00726
2	380	0.28780	0.25190	0.30880	0.10550	0.07244	0.09205	-0.03590	0.02100	-0.03306	-0.01345
2	381	0.55120	0.20620	0.23510	0.21690	0.06268	0.07634	-0.34500	-0.31610	-0.15422	-0.14056
2	382	0.34020	0.29720	0.43690	0.12390	0.07831	0.06169	-0.04300	0.09670	-0.04559	-0.06221
2	383	0.33800	0.28900	0.32930	0.12130	0.08729	0.08397	-0.04900	-0.00870	-0.03401	-0.03733
2	384	0.19870	0.18630	0.24930	0.06847	0.05382	0.05695	-0.01240	0.05060	-0.01465	-0.01152
2	385	0.38760	0.32330	0.39950	0.06236	0.02067	0.01972	-0.06430	0.01190	-0.04169	-0.04264
2	386	0.32780	0.28870	0.32840	0.09945	0.07389	0.09148	-0.03910	0.00060	-0.02556	-0.00797
2	387	0.32210	0.28700	0.34750	0.10230	0.07648	0.10820	-0.03510	0.02540	-0.02582	0.00590
2	388	0.25670	0.23430	0.34450	0.09104	0.07216	0.09458	-0.02240	0.08780	-0.01888	0.00354
2	389	0.31310	0.28510	0.35330	0.10740	0.08682	0.09479	-0.02800	0.04020	-0.02058	-0.01261
2	390	0.22180	0.21800	0.25620	0.07285	0.06485	0.07330	-0.00380	0.03440	-0.00800	0.00045
2	391	0.17290	0.17480	0.21060	0.05973	0.05313	0.06096	0.00190	0.03770	-0.00660	0.00123
2	392	0.25080	0.22100	0.28890	0.08203	0.05997	0.04802	-0.02980	0.03810	-0.02206	-0.03401
2	393	0.27550	0.26210	0.32440	0.09697	0.08073	0.08515	-0.01340	0.04890	-0.01624	-0.01182
2	394	0.19420	0.18020	0.23210	0.07037	0.05634	0.05651	-0.01400	0.03790	-0.01403	-0.01386
2	395	0.25800	0.23290	0.28510	9.84600	0.03238	0.06079	-0.02510	0.02710	-9.81362	-9.78521
2	396	0.42930	0.39160	0.48420	0.01487	0.01449	0.04234	-0.03770	0.05490	-0.00038	0.02747
2	397	0.37220	0.32560	0.42150	0.10450	0.08029	0.10060	-0.04660	0.04930	-0.02421	-0.00390
2	398	0.26980	0.24310	0.30760	0.08858	0.07162	0.08436	-0.02670	0.03780	-0.01696	-0.00422
2	399	0.39740	0.33820	0.42550	0.12030	0.08934	0.08896	-0.05920	0.02810	-0.03096	-0.03134
2	400	0.43790	0.39570	0.50280	0.16000	0.12690	0.13910	-0.04220	0.06490	-0.03310	-0.02090
2	401	0.21070	0.19810	0.25910	0.07374	0.06118	0.07280	-0.01260	0.04840	-0.01256	-0.00094
2	402	0.29250	0.25660	0.34050	0.11060	0.07602	0.08694	-0.03590	0.04800	-0.03458	-0.02366
2	403	0.25580	0.25420	0.32680	0.08250	0.06651	0.07005	-0.00160	0.07100	-0.01599	-0.01245
2	404	0.24130	0.22570	0.29810	0.08494	0.06971	0.06744	-0.01560	0.05680	-0.01523	-0.01750
2	405	0.22740	0.19980	0.25450	0.08106	0.06316	0.07071	-0.02760	0.02710	-0.01790	-0.01035
2	407	0.34570	0.33570	0.40520	0.11920	0.10250	0.10890	-0.01000	0.05950	-0.01670	-0.01030
2	408	0.23900	0.20760	0.29230	0.08471	0.06501	0.08528	-0.03140	0.05330	-0.01970	0.00057
2	409	0.24400	0.22200	0.26140	0.08450	0.06606	0.07609	-0.02200	0.01740	-0.01844	-0.00841
2	410	0.41270	0.41890	0.66000	0.01561	0.01935	0.02620	0.00620	0.24730	0.00374	0.01059
2	411	0.35890	0.32010	0.41150	0.13380	0.11030	0.12320	-0.03880	0.05260	-0.02350	-0.01060
2	413	0.28530	0.25840	0.32480	0.09401	0.08393	0.08975	-0.02690	0.03950	-0.01008	-0.00426
2	414	0.31200	0.28120	0.33410	0.02075	0.01191	0.04818	-0.03080	0.02210	-0.00884	0.02743
2	415	0.26250	0.24600	0.35600	0.09528	0.07443	0.07089	-0.01650	0.09350	-0.02085	-0.02439

Figure F-8. Vendor 2 Refresh Times Measured at V_{CC}=5.5 volts (Worst-case bits)

2	416	0.46300	0.38120	0.45890	0.04434	0.02942	0.03940	-0.08180	-0.00410	-0.01492	-0.00494
2	417	0.33740	0.31190	0.45430	0.11050	0.08133	0.07037	-0.02550	0.11690	-0.02917	-0.04013
2	418	0.20410	0.18940	0.24010	0.07424	0.05863	0.06935	-0.01470	0.03600	-0.01561	-0.00489
2	419	0.47550	0.42220	0.52030	0.02272	0.02463	0.04086	-0.05330	0.04480	0.00191	0.01814
2	420	0.27900	0.27510	0.30630	0.09389	0.07718	0.06963	-0.00390	0.02730	-0.01671	-0.02426
2	421	0.24270	0.22250	0.29410	0.09124	0.07614	0.08351	-0.02020	0.05140	-0.01510	-0.00773
2	422	0.22630	0.20870	0.24450	0.08110	0.06164	0.07282	-0.01760	0.01820	-0.01946	-0.00828
2	423	0.27070	0.24170	0.29540	0.07169	0.05206	0.05296	-0.02900	0.02470	-0.01963	-0.01873
2	424	0.34070	0.29310	0.38040	0.12450	0.08629	0.11130	-0.04760	0.03970	-0.03821	-0.01320
2	425	0.26290	0.22850	0.32010	0.09669	0.07989	0.08934	-0.03440	0.05720	-0.01680	-0.00735
2	426	0.25970	0.22740	0.28360	0.06151	0.05499	0.06060	-0.03230	0.02390	-0.00652	-0.00091
2	427	0.21170	0.20720	0.28150	0.07313	0.06321	0.08575	-0.00450	0.06980	-0.00992	0.01262
2	428	0.23080	0.19970	0.25090	0.07949	0.06076	0.06946	-0.03110	-0.17141	-0.01873	-0.10056
2	429	0.26440	0.27860	0.33030	0.09546	0.08838	0.10940	0.01420	-0.23484	-0.00708	-0.09520
2	430	0.45270	0.43810	0.57380	0.01861	0.01528	0.02561	-0.01460	-0.55519	-0.00333	-0.04021
2	431	0.39040	0.34120	0.41640	0.13390	0.10200	0.12340	-0.04920	-0.28250	-0.03190	-0.17260
2	432	0.20650	0.18840	0.23660	0.06174	0.05163	0.06076	-0.01810	-0.17486	-0.01011	-0.07886
2	433	0.28480	0.27000	0.33380	0.10380	0.08559	0.10450	-0.01480	-0.23000	-0.01821	-0.11930
2	434	0.19680	0.17980	0.21990	0.06342	0.04645	0.05733	-0.01700	-0.15648	-0.01697	-0.07433
2	435	0.39060	0.30720	0.41430	0.03398	0.03801	0.06069	-0.08340	-0.38032	0.00403	-0.14409
2	436	0.22190	0.20850	0.25430	0.07293	0.04862	0.06508	-0.01340	-0.18137	-0.02431	-0.07848
2	437	0.20030	0.18950	0.21080	0.06979	0.04716	0.05632	-0.01080	-0.14101	-0.02263	-0.06712
2	438	0.23380	0.19030	0.24080	0.07267	0.05298	0.06717	-0.04350	-0.16813	-0.01969	-0.11067
2	439	0.34660	0.31830	0.38370	0.11980	0.09809	0.11130	-0.02830	-0.26390	-0.02171	-0.13960
2	440	0.27090	0.24580	0.32540	0.11030	0.09132	0.09337	-0.02510	-0.21510	-0.01898	-0.11847
2	441	0.26950	0.25760	0.32120	0.10000	0.08142	0.11520	-0.01190	-0.22120	-0.01858	-0.12710
2	442	0.34860	0.27890	0.34530	0.01541	0.05628	0.08058	-0.06970	-0.32989	0.04087	-0.15028

Figure F-8. Vendor 2 Refresh Times Measured at V_{CC}=5.5 volts (Worst-case bits)

Vendor 2 Refresh times (seconds) Measured at Vcc=7.0 volts

1000 Random bits

		Mean			Sigma			Mean delta		Sigma delta	
Cell	S/N	0 hrs	160 hrs	4000 hrs	0 hrs	160 hrs	4000 hrs	0 to 160	0 to 4000	0 to 160	0 to 4000
3	329	0.86570	0.89720	0.91920	0.38520	0.39510	0.34300	0.03150	0.05350	0.00990	-0.04220
2	330	0.89520	0.79920	0.92720	0.39180	0.35760	0.34590	-0.09600	0.03200	-0.03420	-0.04590
3	331	0.68780	0.74380	0.96980	0.34180	0.36250	0.37550	0.05600	0.28200	0.02070	0.03370
3	332	0.94270	0.89530	0.95560	0.38030	0.38260	0.35900	-0.04740	0.01290	0.00230	-0.02130
3	333	0.94120	0.80590	0.86600	0.39840	0.36760	0.34830	-0.13530	-0.07520	-0.03080	-0.05010
3	334	0.93340	0.90330	0.83650	0.40610	0.37830	0.32550	-0.03010	-0.09690	-0.02780	-0.08060
3	335	0.97350	0.85470	0.88980	0.39050	0.36660	0.33370	-0.11880	-0.08370	-0.02390	-0.05680
3	337	0.70010	0.76480	0.70720	0.33220	0.36140	0.29280	0.06470	0.00710	0.02920	-0.03940
3	338	1.00300	0.85010	No test	0.40530	0.36290	No test	-0.15290	No test	-0.04240	No test
3	339	0.99780	1.00400	0.98400	0.40680	0.40410	0.37700	0.00620	-0.01380	-0.00270	-0.02980
3	340	1.06400	0.97410	0.98980	0.41520	0.39700	0.37610	-0.08990	-0.07420	-0.01820	-0.03910
3	341	1.04800	0.89040	0.93640	0.45010	0.40000	0.37390	-0.15760	-0.11160	-0.05010	-0.07620
3	342	0.87230	0.87650	0.87490	0.38200	0.37730	0.33850	0.00420	0.00260	-0.00470	-0.04350
2	343	1.05900	1.03600	0.95770	0.41060	0.40090	0.36160	-0.02300	-0.10130	-0.00970	-0.04900
3	344	1.00400	0.91290	0.80650	0.42100	0.37730	0.33170	-0.09110	-0.19750	-0.04370	-0.08930
3	345	0.99450	0.86260	0.84690	0.41330	0.37680	0.33570	-0.13190	-0.14760	-0.03650	-0.07760
3	346	0.87510	0.74770	0.61880	0.37860	0.34660	0.25480	-0.12740	-0.25630	-0.03200	-0.12380
3	347	1.06000	0.96590	0.95520	0.42500	0.38680	0.37280	-0.09410	-0.10480	-0.03820	-0.05220
3	348	1.06300	1.08600	1.05600	0.40980	0.41530	0.36390	0.02300	-0.00700	0.00550	-0.04590
3	349	0.88440	0.90030	0.93920	0.39310	0.39870	0.36800	0.01590	0.05480	0.00560	-0.02510
2	350	0.71240	0.76780	0.66060	0.34780	0.37750	0.27860	0.05540	-0.05180	0.02970	-0.06920
3	351	0.85390	0.83480	0.70920	0.37120	0.38580	0.29870	-0.01910	-0.14470	0.01460	-0.07250
3	352	0.85050	0.80630	0.73640	0.38320	0.36220	0.30600	-0.04420	-0.11410	-0.02100	-0.07720
3	353	0.99590	0.84940	0.76640	0.38690	0.38010	0.31880	-0.14650	-0.22950	-0.00680	-0.06810
3	354	0.87460	0.91120	0.87490	0.37950	0.36440	0.34290	0.03660	0.00030	-0.01510	-0.03660
2	355	0.71870	0.80100	0.71950	0.33640	0.37380	0.29610	0.08230	0.00080	0.03740	-0.04030
3	356	0.73780	0.76460	0.75880	0.36800	0.39220	0.34810	0.02680	0.02100	0.02420	-0.01960
3	357	0.94760	0.78910	1.01300	0.40610	0.36610	0.39810	-0.15850	0.06540	-0.04000	-0.00800
3	358	0.94710	0.82620	0.85870	0.39670	0.35260	0.36030	-0.12090	-0.08840	-0.04410	-0.03640
3	359	0.77940	0.63340	0.75120	0.35140	0.30580	0.33650	-0.14600	-0.02820	-0.04560	-0.01490
2	360	1.19200	1.14100	1.09200	0.48170	0.45830	0.40380	-0.05100	-0.10000	-0.02340	0.07790
2	361	0.84730	0.93250	0.86060	0.38360	0.39050	0.34500	0.08520	0.01330	0.00690	-0.03860
3	362	0.86210	0.84660	1.01900	0.37410	0.37010	0.37200	-0.01550	0.15690	-0.00400	-0.00210
3	363	0.64290	0.70080	0.88190	0.30720	0.33810	0.37280	0.05790	0.23900	0.03090	0.06560
2	364	0.41010	0.64410	0.62370	0.43500	0.31860	0.26310	0.23400	0.21360	-0.11640	-0.17190
2	365	0.03997	0.73770	0.72680	0.68890	0.35440	0.31040	0.69773	0.68683	-0.33450	-0.37850
2	366	0.67110	0.87590	0.88600	0.47280	0.36430	0.34260	0.20480	0.21490	-0.10850	-0.13020
2	367	0.05731	0.64790	0.64160	0.02327	0.30940	0.27370	0.59059	0.58429	0.28613	0.25043
2	368	0.05009	0.60860	0.64470	0.02928	0.29180	0.26750	0.55851	0.59461	0.26252	0.23822
2	369	1.22600	0.92690	1.17600	0.43600	0.38190	0.39010	-0.29910	-0.05000	-0.05410	-0.04590

Figure F-9. Vendor 2 Refresh Times Measured at V_{CC}=7.0 volts (Random bits)

2	370	0.19370	0.65020	0.72180	0.25750	0.30510	0.30190	0.45650	0.52810	0.04760	0.04440
2	371	0.28790	0.67070	0.75360	0.12490	0.31100	0.31140	0.38280	0.46570	0.18610	0.18650
2	372	0.07765	0.61750	0.58500	0.05579	0.28200	0.24070	0.53985	0.50735	0.22621	0.18491
2	373	0.08106	0.84330	0.91490	0.01723	0.36550	0.35300	0.76224	0.83384	0.34827	0.33577
2	374	0.08652	0.55920	0.59620	0.00972	0.26130	0.24800	0.47268	0.50968	0.25158	0.23828
2	375	0.94840	0.92060	1.00900	0.37830	0.39000	0.37150	-0.02780	0.06060	0.01170	-0.00680
3	376	0.98120	0.82250	1.07600	0.38770	0.35440	0.40050	-0.15870	0.09480	-0.03330	0.01280
3	377	1.01200	0.94970	1.03100	0.40270	0.39990	0.39040	-0.06230	0.01900	-0.00280	-0.01230
3	378	1.03200	0.96500	1.22400	0.41520	0.41270	0.41870	-0.06700	0.19200	-0.00250	0.00350
3	379	1.00900	0.90810	1.00700	0.40680	0.39030	0.38610	-0.10090	-0.00200	-0.01650	-0.02070
2	380	0.94190	0.70620	0.87800	0.39330	0.32090	0.34850	-0.23570	-0.06390	-0.07240	-0.04480
2	381	0.82880	0.62120	0.73490	0.41350	0.27950	0.30240	-0.20760	-0.09390	-0.13400	-0.11110
2	382	1.16100	0.89070	1.03300	0.44940	0.39740	0.39400	-0.27030	-0.12800	-0.05200	-0.05540
2	383	1.13700	0.86750	0.91800	0.41300	0.36030	0.34210	-0.26950	-0.21900	-0.05270	-0.07090
2	384	0.76470	0.61440	0.74370	0.37750	0.29650	0.31870	-0.15030	-0.02100	-0.08100	-0.05880
2	385	0.85100	0.65150	0.78880	0.38750	0.30050	0.32320	-0.19950	-0.06220	-0.08700	-0.06430
2	386	0.94730	0.81700	0.87380	0.39960	0.37720	0.35330	-0.13030	-0.07350	-0.02240	-0.04630
2	387	0.87850	0.70450	0.88970	0.37200	0.32700	0.36440	-0.17400	0.01120	-0.04500	-0.00760
2	388	0.91000	0.76700	1.04100	0.37830	0.35280	0.37420	-0.14300	0.13100	-0.02550	-0.00410
2	389	1.06000	0.90650	1.02400	0.40750	0.38090	0.37060	-0.15350	-0.03600	-0.02660	-0.03690
2	390	0.74430	0.70470	0.79730	0.33570	0.32190	0.32430	-0.03960	0.05300	-0.01380	-0.01140
2	391	0.57370	0.55630	0.63240	0.26420	0.25050	0.25970	-0.01740	0.05870	-0.01370	-0.00450
2	392	0.96120	0.74780	0.86200	0.36900	0.34950	0.34560	-0.21340	-0.09920	-0.01950	-0.02340
2	393	0.96630	0.83280	0.95930	0.37280	0.35150	0.34760	-0.13350	-0.00700	-0.02130	-0.02520
2	394	0.53160	0.51230	0.59230	0.25260	0.23660	0.24040	-0.01930	0.06070	-0.01620	-0.01240
2	395	0.55150	0.50810	0.61100	0.26690	0.24500	0.26690	-0.04340	0.05950	-0.02190	0.00000
2	396	0.88140	0.76500	0.93560	0.38820	0.34460	0.35240	-0.11640	0.05420	-0.04360	-0.03580
2	397	0.95720	0.81060	0.95110	0.39980	0.36810	0.36520	-0.14660	-0.00610	-0.03170	-0.03460
2	398	0.90260	0.72690	0.91710	0.35790	0.32230	0.34730	-0.17570	0.01450	-0.03560	-0.01060
2	399	1.08700	0.88490	1.00100	0.42520	0.39670	0.36840	-0.20210	-0.08600	-0.02850	-0.05680
2	400	1.28600	1.09200	1.25700	0.45850	0.39760	0.38370	-0.19400	-0.02900	-0.06090	-0.07480
2	401	0.63070	0.55790	0.70840	0.30760	0.26390	0.30640	-0.07280	0.07770	-0.04370	-0.00120
2	402	0.96470	0.76770	0.94780	0.39810	0.35270	0.36440	-0.19700	-0.01690	-0.04540	-0.03370
2	403	0.87030	0.77030	0.91960	0.39120	0.38950	0.35730	-0.10000	0.04930	-0.00170	-0.03390
2	404	0.73790	0.62520	0.73580	0.35300	0.29370	0.30690	-0.11270	-0.00210	-0.05930	-0.04610
2	405	0.81780	0.63230	0.76120	0.35460	0.29810	0.31380	-0.18550	-0.05660	-0.05650	-0.04080
2	407	1.13600	1.04100	1.16400	0.42210	0.42030	0.40160	-0.09500	0.02800	-0.00180	-0.02050
2	408	0.76840	0.59580	0.89530	0.36870	0.27730	0.36550	-0.17260	0.12690	-0.09140	-0.00320
2	409	0.84150	0.67200	0.77650	0.37600	0.30130	0.31090	-0.16950	-0.06500	-0.07470	-0.06510
2	410	0.83650	0.84350	1.25300	0.38250	0.38590	0.42790	0.00700	0.41650	0.00340	0.04540
2	411	0.96800	0.84760	0.93660	0.40940	0.38740	0.36960	-0.12040	-0.03140	-0.02200	-0.03980
2	413	0.84490	0.75640	0.86230	0.38910	0.35760	0.34750	-0.08850	0.01740	-0.03150	-0.04160
2	414	0.64790	0.42040	0.66280	0.31710	0.34460	0.28170	-0.22750	0.01490	0.02750	-0.03540
2	415	0.91510	0.76830	0.90830	0.38660	0.35150	0.35650	-0.14680	-0.00680	-0.03510	-0.03010

Figure F-9. Vendor 2 Refresh Times Measured at V_{CC}=7.0 volts (Random bits)

2	416	0.96160	0.76830	0.87100	0.39580	0.34130	0.33240	-0.19330	-0.09060	-0.05450	-0.06340
2	417	1.07200	0.90220	1.05200	0.42410	0.40150	0.40320	-0.16980	-0.02000	-0.02260	-0.02090
2	418	0.72530	0.59360	0.69970	0.34950	0.27390	0.29480	-0.13170	-0.02560	-0.07560	-0.05470
2	419	0.93120	0.83030	0.91430	0.38910	0.37710	0.35950	-0.10090	-0.01690	-0.01200	-0.02960
2	420	0.84910	0.79990	0.74150	0.36520	0.37480	0.31130	-0.04920	-0.10760	0.00960	-0.05390
2	421	0.84740	0.66000	0.86770	0.37650	0.30760	0.33620	-0.18740	0.02030	-0.06890	-0.04030
2	422	0.70250	0.57150	0.64500	0.33410	0.25790	0.26990	-0.13100	-0.05750	-0.07620	-0.06420
2	423	0.71640	0.58580	0.67470	0.35090	0.27520	0.29750	-0.13060	-0.04170	-0.07570	-0.05340
2	424	1.05900	0.85190	1.01100	0.41450	0.35550	0.37020	-0.20710	-0.04800	-0.05900	-0.04430
2	425	0.94210	0.75460	0.94060	0.38610	0.34500	0.36050	-0.18750	-0.00150	-0.04110	-0.02560
2	426	0.70430	0.57890	0.70600	0.34810	0.27350	0.31460	-0.12540	0.00170	-0.07460	-0.03350
2	427	0.78190	0.67660	0.95240	0.36280	0.31410	0.37840	-0.10530	0.17050	-0.04870	0.01560
2	428	0.69090	0.54050	0.65590	0.33340	0.24670	0.27980	-0.15040	-0.03500	-0.08670	-0.05360
2	429	0.94240	0.92170	1.05600	0.39900	0.39260	0.39350	-0.02070	0.11360	-0.00640	-0.00550
2	430	0.87320	0.84630	1.00400	0.38760	0.37930	0.38840	-0.02690	0.13080	-0.00830	0.00080
2	431	1.09700	0.91190	1.04200	0.42550	0.38030	0.38370	-0.18510	-0.05500	-0.04520	-0.04180
2	432	0.57310	0.47570	0.59230	0.27890	0.21850	0.25940	-0.09740	0.01920	-0.06040	-0.01950
2	433	0.96410	0.86220	1.00000	0.39080	0.36870	0.37390	-0.10190	0.03590	-0.02210	-0.01690
2	434	0.62730	0.52270	0.60750	0.30150	0.23830	0.25020	-0.10460	-0.01980	-0.06320	-0.05130
2	435	0.81220	0.60240	0.83250	0.36120	0.26500	0.32960	-0.20980	0.02030	-0.09620	-0.03160
2	436	0.60590	0.51690	0.63290	0.29510	0.24570	0.27950	-0.08900	0.02700	-0.04940	-0.01560
2	437	0.67600	0.54760	0.59970	0.31820	0.24860	0.24870	-0.12840	-0.07630	-0.06960	-0.06950
2	438	0.73310	0.53990	0.65470	0.36820	0.25470	0.28090	-0.19320	-0.07840	-0.11350	-0.08730
2	439	1.06100	0.92420	0.99450	0.43360	0.40310	0.37040	-0.13680	-0.06650	-0.03050	-0.06320
2	440	0.90980	0.77000	0.91240	0.38250	0.35720	0.36490	-0.13980	0.00260	-0.02530	-0.01760
2	441	0.92610	0.83870	1.00400	0.40950	0.37870	0.39060	-0.08740	0.07790	-0.03080	-0.01890
2	442	0.84880	0.65710	0.81510	0.36880	0.31700	0.34590	-0.19170	-0.03370	-0.05180	-0.02290

Figure F-9. Vendor 2 Refresh Times Measured at V_{CC}=7.0 volts (Random bits)

Vendor 2 Refresh times (seconds) Measured at Vcc=7.0 volts

1000 Worst case bits

		Mean			Sigma			Mean delta		Sigma delta	
Cell	S/N	0 hrs	160 hrs	4000 hrs	0 hrs	160 hrs	4000 hrs	0 to 160	0 to 4000	0 to 160	0 to 4000
3	329	0.26590	0.28470	0.34960	0.22600	0.22620	0.23620	0.01880	0.08370	0.00020	0.01020
2	330	0.15970	0.15760	0.21980	0.10240	0.08649	0.09892	-0.00210	0.06010	-0.01591	-0.00348
3	331	0.15190	0.16750	0.26210	0.09126	0.09364	0.10850	0.01560	0.11020	0.00238	0.01724
3	332	0.31360	0.29760	0.36720	0.32060	0.28210	0.31840	-0.01600	0.05360	-0.03850	-0.00220
3	333	0.32180	0.28220	0.32370	0.12490	0.10250	0.12700	-0.03960	0.00190	-0.02240	0.00210
3	334	0.25780	0.25500	0.27320	0.27350	0.24990	0.23250	-0.00280	0.01540	-0.02360	-0.04100
3	335	0.28230	0.25120	0.29240	0.31400	0.25690	0.25970	-0.03110	0.01010	-0.05710	-0.05430
3	337	0.13710	0.15190	0.17570	0.08640	0.08991	0.08301	0.01480	0.03860	0.00351	-0.00339
3	338	0.31420	0.26870	No test	0.32120	0.24540	No test	-0.04550	No test	-0.07580	No test
3	339	0.44850	0.44730	0.48030	0.47920	0.46540	0.44810	-0.00120	0.03180	-0.01380	-0.03110
3	340	0.21130	0.21130	0.24940	0.14050	0.13330	0.13300	0.00000	0.03810	-0.00720	-0.00750
3	341	0.38210	0.34370	0.39280	0.08551	0.07261	0.07710	-0.03840	0.01070	-0.01290	-0.00841
3	342	0.21540	0.22400	0.25590	0.20960	0.20570	0.20520	0.00860	0.04050	-0.00390	-0.00440
2	343	0.33830	0.33550	0.35180	0.17640	0.16090	0.15430	-0.00280	0.01350	-0.01550	-0.02210
3	344	0.40080	0.36170	0.34460	0.47440	0.40360	0.34060	-0.03910	-0.05620	-0.07080	-0.13380
3	345	0.20130	0.18410	0.21190	0.18430	0.14710	0.14520	-0.01720	0.01060	-0.03720	-0.03910
3	346	0.35100	0.31190	0.30030	0.28600	0.24100	0.20820	-0.03910	-0.05070	-0.04500	-0.07780
3	347	0.31570	0.30010	0.33270	0.32640	0.29380	0.29390	-0.01560	0.01700	-0.03260	-0.03250
3	348	0.34120	0.35350	0.38310	0.40930	0.40510	0.39320	0.01230	0.04190	-0.00420	-0.01610
3	349	0.19920	0.20030	0.25270	0.12760	0.12350	0.12990	0.00110	0.05350	-0.00410	0.00230
2	350	0.17310	0.19480	0.21060	0.10470	0.10520	0.09790	0.02170	0.03750	0.00050	-0.00680
3	351	0.29200	0.28970	0.28990	0.30770	0.29590	0.26590	-0.00230	-0.00210	-0.01180	-0.04180
3	352	0.24370	0.23750	0.25830	0.23880	0.22170	0.20840	-0.00620	0.01460	-0.01710	-0.03040
3	353	0.26100	0.22570	0.24440	0.26440	0.20620	0.19450	-0.03530	-0.01660	-0.05820	-0.06990
3	354	0.23960	0.25350	0.26990	0.25560	0.26390	0.25460	0.01390	0.03030	0.00830	-0.00100
2	355	0.31860	0.33720	0.35440	0.04538	0.05198	0.06879	0.01860	0.03580	0.00660	0.02341
3	356	0.21870	0.22330	0.25280	0.11410	0.10980	0.10760	0.00460	0.03410	-0.00430	-0.00650
3	357	0.21250	0.18990	0.23990	0.13360	0.10870	0.14560	-0.02260	0.02740	-0.02490	0.01200
3	358	0.15840	0.14910	0.17790	0.10480	0.09035	0.09685	-0.00930	0.01950	-0.01445	-0.00795
3	359	0.23160	0.20370	0.23830	0.24520	0.20330	0.24110	-0.02790	0.00670	-0.04190	-0.00410
2	360	0.42010	0.40820	0.43800	0.49970	0.46790	0.43970	-0.01190	0.01790	-0.03180	-0.06000
2	361	0.17740	0.18940	0.21380	0.11680	0.12280	0.11850	0.01200	0.03640	0.00600	0.00170
3	362	0.28500	0.27870	0.37860	0.32940	0.30440	0.38610	-0.00630	0.09360	-0.02500	0.05670
3	363	0.25870	0.27490	0.34450	0.25440	0.26840	0.33540	0.01620	0.08580	0.01400	0.08100
2	364	0.05113	0.29230	0.31820	0.01818	0.01469	0.03386	0.24117	0.26707	-0.00349	0.01568
2	365	Not avail	0.14370	0.16480	Not avail	0.08907	0.08855	Not avail	Not avail	Not avail	Not avail
2	366	0.14840	0.15720	0.18500	0.09447	0.09901	0.10660	0.00880	0.03660	0.00454	0.01213
2	367	0.07073	0.21460	0.23560	0.02998	0.17910	0.18150	0.14387	0.16487	0.14912	0.15152
2	368	0.05602	0.17300	0.20430	0.02519	0.15160	0.16720	0.11698	0.14828	0.12641	0.14201
2	369	0.31950	0.24580	0.35390	0.37750	0.25470	0.35220	-0.07370	0.03440	-0.12280	-0.02530

Figure F-10. Vendor 2 Refresh Times Measured at V_{CC}=7.0 volts (Worst-case bits)

2	370	0.09841	0.21880	0.26550	0.01923	0.21140	0.23370	0.12039	0.16709	0.19217	0.21447
2	371	0.20320	0.29450	0.34750	0.11820	0.28420	0.31150	0.09130	0.14430	0.16600	0.19330
2	372	0.05080	0.27870	0.28820	0.03895	0.24090	0.23280	0.22790	0.23740	0.20195	0.19385
2	373	0.08027	0.28370	0.33980	0.00160	0.22960	0.25060	0.20343	0.25953	0.22800	0.24900
2	374	0.08502	0.20880	0.24620	0.02327	0.14690	0.15950	0.12378	0.16118	0.12363	0.13623
2	375	0.36030	0.34970	0.42020	0.13340	0.12480	0.14410	-0.01060	0.05990	-0.00860	0.01070
3	376	0.20250	0.17810	0.21920	0.13510	0.11050	0.14820	-0.02440	0.01670	-0.02460	0.01310
3	377	0.23520	0.19060	0.27890	0.15410	0.14060	0.15790	-0.04460	0.04370	-0.01350	0.00380
3	378	0.21140	0.16780	0.24790	0.13450	0.12030	0.15310	-0.04360	0.03650	-0.01420	0.01860
3	379	0.20660	0.19460	0.24590	0.13300	0.11550	0.12870	-0.01200	0.03930	-0.01750	-0.00430
2	380	0.23050	0.18860	0.24560	0.13760	0.10640	0.13450	-0.04190	0.01510	-0.03120	-0.00310
2	381	0.50050	0.14520	0.18170	0.23570	0.08496	0.10060	-0.35530	-0.31880	-0.15074	-0.13510
2	382	0.23150	0.19280	0.29680	0.14210	0.10580	0.10850	-0.03870	0.06530	-0.03630	-0.03360
2	383	0.22760	0.19100	0.23260	0.14790	0.11060	0.11570	-0.03660	0.00500	-0.03730	-0.03220
2	384	0.14750	0.13370	0.18880	0.09373	0.07614	0.08697	-0.01380	0.04130	-0.01759	-0.00676
2	385	0.39490	0.32360	0.40760	0.02096	0.01308	0.02688	-0.07130	0.01270	-0.00788	0.00592
2	386	0.26560	0.22660	0.27940	0.14060	0.10970	0.11760	-0.03900	0.01380	-0.03090	-0.02300
2	387	0.26510	0.22540	0.29730	0.13640	0.10770	0.13730	-0.03970	0.03220	-0.02870	0.00090
2	388	0.18340	0.17750	0.25950	0.12010	0.10390	0.13520	-0.00590	0.07610	-0.01620	0.01510
2	389	0.20220	0.18380	0.24430	0.12910	0.10610	0.12270	-0.01840	0.04210	-0.02300	-0.00640
2	390	0.13840	0.13760	0.17210	0.08305	0.07972	0.09213	-0.00080	0.03370	-0.00333	0.00908
2	391	0.12170	0.12250	0.15620	0.07490	0.07085	0.08506	0.00080	0.03450	-0.00405	0.01016
2	392	0.16660	0.14780	0.20560	0.10170	0.07959	0.08367	-0.01880	0.03900	-0.02211	-0.01803
2	393	0.17270	0.16120	0.21610	0.10770	0.09203	0.10540	-0.01150	0.04340	-0.01567	-0.00230
2	394	0.15320	0.13860	0.18560	0.09194	0.07706	0.09007	-0.01460	0.03240	-0.01488	-0.00187
2	395	0.25480	0.23600	0.30620	0.01161	9.90100	0.01245	-0.01880	0.05140	9.88939	0.00084
2	396	0.41340	0.37250	0.47600	0.01692	0.01656	0.01966	-0.04090	0.06260	-0.00036	0.00274
2	397	0.31500	0.26970	0.36240	0.14360	0.11570	0.14170	-0.04530	0.04740	-0.02790	-0.00190
2	398	0.18150	0.16030	0.21860	0.11820	0.09463	0.12000	-0.02120	0.03710	-0.02357	0.00180
2	399	0.30670	0.25860	0.33720	0.16580	0.13040	0.13740	-0.04810	0.03050	-0.03540	-0.02840
2	400	0.32590	0.29000	0.38410	0.19970	0.16530	0.18700	-0.03590	0.05820	-0.03440	-0.01270
2	401	0.17160	0.15960	0.21680	0.09575	0.08341	0.10530	-0.01200	0.04520	-0.01234	0.00955
2	402	0.24380	0.19850	0.27020	0.14590	0.10850	0.14590	-0.04530	0.02640	-0.03740	0.00000
2	403	0.18410	0.17760	0.24370	0.11080	0.09880	0.11310	-0.00650	0.05960	-0.01200	0.00230
2	404	0.17690	0.16240	0.22150	0.10620	0.09186	0.09771	-0.01450	0.04460	-0.01434	-0.00849
2	405	0.16570	0.14640	0.20100	0.10570	0.08651	0.10320	-0.01930	0.03530	-0.01919	-0.00250
2	407	0.22800	0.21930	0.28420	0.14590	0.13040	0.14210	-0.00870	0.05620	-0.01550	-0.00380
2	408	0.19230	0.16140	0.25100	0.11470	0.08935	0.12550	-0.03090	0.05870	-0.02535	0.01080
2	409	0.16210	0.14620	0.18530	0.10410	0.08626	0.09988	-0.01590	0.02320	-0.01784	-0.00422
2	410	0.44750	0.44730	0.70400	0.02611	0.02491	0.03849	-0.00020	0.25650	-0.00120	0.01238
2	411	0.28520	0.25320	0.33950	0.17060	0.13920	0.15150	-0.03200	0.05430	-0.03140	-0.01910
2	413	0.24520	0.23010	0.28970	0.12370	0.10980	0.12200	-0.01510	0.04450	-0.01390	-0.00170
2	414	0.30980	0.26070	0.34570	0.02778	0.06644	0.03944	-0.04910	0.03590	0.03866	0.01166
2	415	0.18230	0.16600	0.25570	0.12120	0.09787	0.10470	-0.01630	0.07340	-0.02333	-0.01650

Figure F-10. Vendor 2 Refresh Times Measured at V_{CC}=7.0 volts (Worst-case bits)

2	416	0.44130	0.36010	0.43690	0.06130	0.04755	0.04899	-0.08120	-0.00440	-0.01375	-0.01231
2	417	0.24280	0.21800	0.33080	0.14850	0.12010	0.11910	-0.02480	0.08800	-0.02840	-0.02940
2	418	0.15010	0.14350	0.18880	0.09681	0.08136	0.09239	-0.00660	0.03870	-0.01545	-0.00442
2	419	0.47110	0.41640	0.50660	0.02556	0.02553	0.02539	-0.05470	0.03550	-0.00003	-0.00017
2	420	0.21630	0.20910	0.24910	0.12680	0.11280	0.09940	-0.00720	0.03280	-0.01400	-0.02740
2	421	0.16770	0.16130	0.22160	0.11440	0.09700	0.11250	-0.00640	0.05390	-0.01740	-0.00190
2	422	0.18610	0.16560	0.19980	0.11000	0.09070	0.10330	-0.02050	0.01370	-0.01930	-0.00670
2	423	0.25890	0.22740	0.27860	0.08000	0.06615	0.07551	-0.03150	0.01970	-0.01385	-0.00449
2	424	0.25400	0.21840	0.29370	0.16110	0.12510	0.15080	-0.03560	0.03970	-0.03600	-0.01030
2	425	0.19330	0.17090	0.24820	0.12760	0.10070	0.11850	-0.02240	0.05490	-0.02690	-0.00910
2	426	0.23000	0.20370	0.25900	0.09139	0.07468	0.08762	-0.02630	0.02900	-0.01671	-0.00377
2	427	0.14940	0.14380	0.21150	0.09638	0.08464	0.11460	-0.00560	0.06210	-0.01174	0.01822
2	428	0.18780	0.15960	0.20860	0.10570	0.08154	0.09881	-0.02820	0.02080	-0.02416	-0.00689
2	429	0.17480	0.17870	0.23300	0.11660	0.11200	0.13490	0.00390	0.05820	-0.00460	0.01830
2	430	0.47060	0.45170	0.59120	0.02781	0.02579	0.03235	-0.01890	0.12060	-0.00202	0.00454
2	431	0.30510	0.26400	0.33660	0.17840	0.14270	0.16830	-0.04110	0.03150	-0.03570	-0.01010
2	432	0.17570	0.16180	0.20280	0.08575	0.07433	0.09073	-0.01390	0.02710	-0.01142	0.00498
2	433	0.19790	0.18480	0.24760	0.13040	0.11290	0.13430	-0.01310	0.04970	-0.01750	0.00390
2	434	0.14500	0.13580	0.17140	0.08728	0.07229	0.08666	-0.00920	0.02640	-0.01499	-0.00062
2	435	0.39470	0.31330	0.42770	0.01868	0.01815	0.03114	-0.08140	0.03300	-0.00053	0.01246
2	436	0.20090	0.17360	0.22480	0.09212	0.07961	0.09980	-0.02730	0.02390	-0.01251	0.00768
2	437	0.14490	0.12750	0.15480	0.08816	0.06926	0.07707	-0.01740	0.00990	-0.01890	-0.01109
2	438	0.19270	0.16370	0.20920	0.10410	0.07820	0.10060	-0.02900	0.01650	-0.02590	-0.00350
2	439	0.27200	0.24590	0.30920	0.15930	0.13570	0.15060	-0.02610	0.03720	-0.02360	-0.00870
2	440	0.22350	0.21400	0.25780	0.12770	0.11000	0.13260	-0.00950	0.03430	-0.01770	0.00490
2	441	0.20260	0.17850	0.26830	0.12870	0.10410	0.13790	-0.02410	0.06570	-0.02460	0.00920
2	442	0.33650	0.27500	0.36210	0.01281	0.05064	0.01657	-0.06150	0.02560	0.03783	0.00376

Figure F-10. Vendor 2 Refresh Times Measured at V_{CC}=7.0 volts (Worst-case bits)

Vendor 2 Refresh times (seconds) Measured at Vcc=8.0 volts

1000 Random bits

		Mean			Sigma			Mean delta		Sigma delta	
Cell	S/N	0 hrs	160 hrs	4000 hrs	0 hrs	160 hrs	4000 hrs	0 to 160	0 to 4000	0 to 160	0 to 4000
3	329	0.93470	0.97360	1.01400	0.40820	0.42040	0.38800	0.03890	0.07930	0.01220	-0.02020
2	330	0.97340	0.89190	1.03600	0.42850	0.39120	0.38890	-0.08150	0.06260	-0.03730	-0.03960
3	331	0.77360	0.83260	1.10600	0.38580	0.40540	0.40830	0.05900	0.33240	0.01960	0.02250
3	332	1.01600	0.95670	1.04800	0.41500	0.38550	0.39720	-0.05930	0.03200	-0.02950	-0.01780
3	333	1.03300	0.89950	0.97520	0.42240	0.40670	0.38690	-0.13350	-0.05780	-0.01570	-0.03550
3	334	1.00400	0.97000	0.92520	0.40540	0.41030	0.35710	-0.03400	-0.07880	0.00490	-0.04830
3	335	1.05400	0.92060	0.96550	0.43120	0.39290	0.37020	-0.13340	-0.08850	-0.03830	-0.06100
3	337	0.79020	0.85570	0.83330	0.37460	0.39680	0.34090	0.06550	0.04310	0.02220	-0.03370
3	338	1.09000	0.91520	No test	0.44490	0.38960	No test	-0.17480	No test	-0.05530	No test
3	339	1.08000	1.08200	1.06800	0.43930	0.43600	0.40950	0.00200	-0.01200	-0.00330	-0.02980
3	340	1.18600	1.07000	1.12000	0.46940	0.44300	0.42620	-0.11600	-0.06600	-0.02640	-0.04320
3	341	1.12400	0.95260	1.03100	0.49470	0.42960	0.41790	-0.17140	-0.09300	-0.06510	-0.07680
3	342	0.94390	0.94350	0.96860	0.41340	0.40320	0.37390	-0.00040	0.02470	-0.01020	-0.03950
2	343	1.16600	1.13500	1.06100	0.46000	0.45180	0.40770	-0.03100	-0.10500	-0.00820	-0.05230
3	344	1.09700	0.98390	0.89430	0.43790	0.40710	0.36000	-0.11310	-0.20270	-0.03080	-0.07790
3	345	1.10300	0.95180	0.95110	0.44720	0.40990	0.36790	-0.15120	-0.15190	-0.03730	-0.07930
3	346	0.96140	0.83050	0.73200	0.41800	0.38510	0.31060	-0.13090	-0.22940	-0.03290	-0.10740
3	347	1.13700	1.02600	1.03200	0.43720	0.41180	0.40330	-0.11100	-0.10500	-0.02540	-0.03390
3	348	1.14400	1.16300	1.15400	0.45020	0.45250	0.40780	0.01900	0.01000	0.00230	-0.04240
3	349	0.96980	0.99610	1.08400	0.42230	0.43100	0.41580	0.02630	0.11420	0.00870	-0.00650
2	350	0.80330	0.85650	0.77220	0.39280	0.38700	0.33370	0.05320	-0.03110	-0.00580	-0.05910
3	351	0.93980	0.91840	0.82460	0.40680	0.41650	0.34410	-0.02140	-0.11520	0.00970	-0.06270
3	352	0.92930	0.88470	0.85150	0.41250	0.39970	0.34710	-0.04460	-0.07780	-0.01280	-0.06540
3	353	1.10400	0.93000	0.89790	0.43980	0.40630	0.35240	-0.17400	-0.20610	-0.03350	-0.08740
3	354	0.94190	0.98890	0.96160	0.38340	0.40230	0.36940	0.04700	0.01970	0.01890	-0.01400
2	355	0.80700	0.89270	0.85130	0.37380	0.41090	0.34740	0.08570	0.04430	0.03710	-0.02640
3	356	0.84350	0.86820	0.88990	0.38860	0.40360	0.39700	0.02470	0.04640	0.01500	0.00840
3	357	1.06500	0.89280	1.14200	0.44010	0.41050	0.44490	-0.17220	0.07700	-0.02960	0.00480
3	358	0.98090	0.89960	0.95210	0.41120	0.38710	0.39240	-0.08130	-0.02880	-0.02410	-0.01880
3	359	0.86030	0.70280	0.84450	0.39430	0.34780	0.37710	-0.15750	-0.01580	-0.04650	-0.01720
2	360	1.29000	1.23000	1.18900	0.52380	0.50410	0.41900	-0.06000	-0.10100	-0.01970	-0.10480
2	361	0.95060	1.02100	0.95300	0.40090	0.42930	0.37860	0.07040	0.00240	0.02840	-0.02230
3	362	0.93120	0.91840	1.14600	0.39950	0.39630	0.41480	-0.01280	0.21480	-0.00320	0.01530
3	363	0.72120	0.78830	0.97500	0.35110	0.38000	0.40850	0.06710	0.25380	0.02890	0.05740
2	364	0.04780	0.72490	0.73140	0.00906	0.36090	0.32220	0.67710	0.68360	0.35184	0.31314
2	365	0.29140	0.83840	0.86280	0.05067	0.39860	0.35990	0.54700	0.57140	0.34793	0.30923
2	366	0.09305	0.97480	0.99820	0.11260	0.40380	0.38700	0.88175	0.90515	0.29120	0.27440
2	367	0.27390	0.72730	0.74550	0.28490	0.35480	0.32710	0.45340	0.47160	0.06990	0.04220
2	368	0.18100	0.69130	0.77150	0.11930	0.33910	0.33090	0.51030	0.59050	0.21980	0.21160
2	369	1.32700	0.99000	1.26900	0.49630	0.40400	0.40310	-0.33700	-0.05800	-0.09230	-0.09320

Figure F-11. Vendor 2 Refresh Times Measured at V_{CC}=8.0 volts (Random bits)

2	370	1.00600	0.72210	0.84070	0.44450	0.34860	0.35080	-0.28390	-0.16530	-0.09590	-0.09370
2	371	0.33310	0.74130	0.86610	0.20410	0.34570	0.34960	0.40820	0.53300	0.14160	0.14550
2	372	0.32640	0.68930	0.68040	0.18030	0.32760	0.29180	0.36290	0.35400	0.14730	0.11150
2	373	0.69280	0.91630	0.99920	0.52480	0.39610	0.38340	0.22350	0.30640	-0.12870	-0.14140
2	374	0.61050	0.62560	0.68250	0.27500	0.30080	0.29890	0.01510	0.07200	0.02580	0.02390
2	375	1.02100	0.98080	1.08100	0.41110	0.41200	0.41940	-0.04020	0.06000	0.00090	0.00830
3	376	1.06300	0.88770	1.17800	0.43400	0.38610	0.43800	-0.17530	0.11500	-0.04790	0.00400
3	377	1.08000	0.99820	1.11900	0.44040	0.41580	0.42340	-0.08180	0.03900	-0.02460	-0.01700
3	378	1.11700	1.01100	1.31900	0.45260	0.43350	0.46890	-0.10600	0.20200	-0.01910	0.01630
3	379	1.09000	0.97240	1.09400	0.43540	0.41210	0.41790	-0.11760	0.00400	-0.02330	-0.01750
2	380	1.02800	0.78430	0.97760	0.43570	0.35630	0.38060	-0.24370	-0.05040	-0.07940	-0.05510
2	381	0.90340	0.69590	0.84680	0.45760	0.31870	0.34160	-0.20750	-0.05660	-0.13890	-0.11600
2	382	1.25100	0.95350	1.11900	0.48920	0.42210	0.42650	-0.29750	-0.13200	-0.06710	-0.06270
2	383	1.21700	0.92920	1.00600	0.45390	0.39410	0.37460	-0.28780	-0.21100	-0.05980	-0.07930
2	384	0.88470	0.70070	0.88530	0.42340	0.33880	0.36660	-0.18400	0.00060	-0.08460	-0.05680
2	385	0.93280	0.72360	0.89670	0.39500	0.33270	0.36330	-0.20920	-0.03610	-0.06230	-0.03170
2	386	1.03300	0.88070	0.95020	0.44130	0.40180	0.38410	-0.15230	-0.08280	-0.03950	-0.05720
2	387	0.95300	0.78080	0.97290	0.41300	0.36980	0.40290	-0.17220	0.01990	-0.04320	-0.01010
2	388	0.99330	0.85900	1.16400	0.41540	0.39070	0.42090	-0.13430	0.17070	-0.02470	0.00550
2	389	1.14300	0.96400	1.11300	0.44100	0.40230	0.40780	-0.17900	-0.03000	-0.03870	-0.03320
2	390	0.81170	0.76560	0.89290	0.37040	0.35130	0.36150	-0.04610	0.08120	-0.01910	-0.00890
2	391	0.64210	0.62520	0.73550	0.30440	0.29800	0.31470	-0.01690	0.09340	-0.00640	0.01030
2	392	1.05500	0.82640	0.97810	0.42030	0.38700	0.38420	-0.22860	-0.07690	-0.03330	-0.03610
2	393	1.03200	0.90290	1.04500	0.40770	0.38210	0.38660	-0.12910	0.01300	-0.02560	-0.02110
2	394	0.67590	0.56740	0.69200	0.33510	0.27150	0.29980	-0.10850	0.01610	-0.06360	-0.03530
2	395	0.61570	0.56230	0.71440	0.30890	0.28300	0.32200	-0.05340	0.09870	-0.02590	0.01310
2	396	0.94690	0.83300	1.01200	0.39140	0.37620	0.39410	-0.11390	0.06510	-0.01520	0.00270
2	397	1.04200	0.88500	1.04500	0.44030	0.39430	0.40710	-0.15700	0.00300	-0.04600	-0.03320
2	398	0.97100	0.79550	1.00300	0.39270	0.35370	0.38490	-0.17550	0.03200	-0.03900	-0.00780
2	399	1.16000	0.94600	1.09100	0.45490	0.41980	0.41160	-0.21400	-0.06900	-0.03510	-0.04330
2	400	1.36900	1.15600	1.34700	0.50160	0.42360	0.42380	-0.21300	-0.02200	-0.07800	-0.07780
2	401	0.71710	0.63170	0.83430	0.36050	0.31520	0.36650	-0.08540	0.11720	-0.04530	0.00600
2	402	1.06500	0.85830	1.05100	0.43480	0.38980	0.38110	-0.20670	-0.01400	-0.04500	-0.05370
2	403	0.93720	0.87610	1.00700	0.41340	0.39330	0.39270	-0.06110	0.06980	-0.02010	-0.02070
2	404	0.81360	0.68740	0.82640	0.38690	0.33080	0.34550	-0.12620	0.01280	-0.05610	-0.04140
2	405	0.91320	0.68970	0.88090	0.39700	0.35110	0.35530	-0.22350	-0.03230	-0.04590	-0.04170
2	407	1.19700	1.11000	1.24700	0.44760	0.42360	0.44120	-0.08700	0.05000	-0.02400	-0.00640
2	408	0.87080	0.67670	1.00900	0.41390	0.32350	0.41110	-0.19410	0.13820	-0.09040	-0.00280
2	409	0.92190	0.74410	0.86980	0.41140	0.34030	0.35600	-0.17780	-0.05210	-0.07110	-0.05540
2	410	0.93420	0.95870	1.38300	0.42170	0.43810	0.48390	0.02450	0.44880	0.01640	0.06220
2	411	1.04900	0.90660	1.02000	0.44440	0.41170	0.40210	-0.14240	-0.02900	-0.03270	-0.04230
2	413	0.92140	0.84200	0.95330	0.39020	0.38710	0.38450	-0.07940	0.03190	-0.00310	-0.00570
2	414	0.72730	0.63450	0.77740	0.36090	0.31190	0.33650	-0.09280	0.05010	-0.04900	-0.02440
2	415	1.00100	0.84140	0.99290	0.42570	0.38200	0.38900	-0.15960	-0.00810	-0.04370	-0.03670

Figure F-11. Vendor 2 Refresh Times Measured at V_{CC}=8.0 volts (Random bits)

2	416	1.04500	0.83270	0.94140	0.43340	0.37000	0.36380	-0.21230	-0.10360	-0.06340	-0.06960
2	417	1.17400	0.97370	1.14000	0.46820	0.42980	0.43450	-0.20030	-0.03400	-0.03840	-0.03370
2	418	0.82680	0.66650	0.82130	0.39790	0.31650	0.34520	-0.16030	-0.00550	-0.08140	-0.05270
2	419	1.01300	0.90390	0.99530	0.42680	0.40040	0.39430	-0.10910	-0.01770	-0.02640	-0.03250
2	420	0.92900	0.88200	0.85620	0.40140	0.41040	0.35570	-0.04700	-0.07280	0.00900	-0.04570
2	421	0.94790	0.80990	0.96440	0.41340	0.35950	0.37030	-0.13800	0.01650	-0.05390	-0.04310
2	422	0.78250	0.63860	0.75210	0.37370	0.30000	0.32250	-0.14390	-0.03040	-0.07370	-0.05120
2	423	0.81220	0.64680	0.78420	0.40070	0.31220	0.35000	-0.16540	-0.02800	-0.08850	-0.05070
2	424	1.14000	0.92360	1.09900	0.44560	0.38680	0.40130	-0.21640	-0.04100	-0.05880	-0.04430
2	425	1.03800	0.84280	1.04700	0.40880	0.38230	0.40430	-0.19520	0.00900	-0.02650	-0.00450
2	426	0.78950	0.63600	0.81910	0.39560	0.30690	0.36360	-0.15350	0.02960	-0.08870	-0.03200
2	427	0.86710	0.75920	1.05500	0.39820	0.35280	0.40020	-0.10790	0.18790	-0.04540	0.00200
2	428	0.77240	0.59670	0.76460	0.37730	0.28270	0.33390	-0.17570	-0.38730	-0.09460	-0.50960
2	429	1.01900	0.99640	1.16500	0.43280	0.41890	0.43350	-0.02260	-0.73220	-0.01390	-0.45610
2	430	0.94920	0.92150	1.13700	0.41700	0.40950	0.42990	-0.02770	-0.72000	-0.00750	-0.45760
2	431	1.17800	0.98100	1.14400	0.43660	0.40480	0.41450	-0.19700	-0.70740	-0.03180	-0.61150
2	432	0.64230	0.56440	0.68380	0.32500	0.27890	0.31250	-0.07790	-0.35880	-0.04610	-0.39040
2	433	1.04900	0.93890	1.10100	0.42930	0.40810	0.42400	-0.11010	-0.67170	-0.02120	-0.53410
2	434	0.69990	0.58920	0.70570	0.34290	0.28570	0.30730	-0.11070	-0.36280	-0.05720	-0.41800
2	435	0.92280	0.69330	0.95860	0.41110	0.31870	0.36980	-0.22950	-0.54750	-0.09240	-0.59930
2	436	0.67560	0.57640	0.73690	0.34000	0.28380	0.33080	-0.09920	-0.39690	-0.05620	-0.43000
2	437	0.75720	0.60810	0.69140	0.36650	0.28480	0.30030	-0.14910	-0.32490	-0.08170	-0.44940
2	438	0.83850	0.60540	0.76700	0.38600	0.29760	0.33460	-0.23310	-0.38100	-0.08840	-0.56770
2	439	1.15400	0.99510	1.09000	0.48120	0.43780	0.41710	-0.15890	-0.60880	-0.04340	-0.57600
2	440	0.99450	0.85740	1.00700	0.42360	0.39280	0.40260	-0.13710	-0.58340	-0.03080	-0.53970
2	441	1.01000	0.92050	1.13100	0.42900	0.40900	0.43580	-0.08950	-0.70200	-0.02000	-0.52530
2	442	0.93150	0.75400	0.91650	0.41400	0.36460	0.38120	-0.17750	-0.50250	-0.04940	-0.55870

Figure F-11. Vendor 2 Refresh Times Measured at V_{CC}=8.0 volts (Random bits)

Vendor 2 Refresh times (seconds) Measured at Vcc=8.0 volts

1000 Worst case bits

		Mean			Sigma			Mean delta		Sigma delta	
Cell	S/N	0 hrs	160 hrs	4000 hrs	0 hrs	160 hrs	4000 hrs	0 to 160	0 to 4000	0 to 160	0 to 4000
3	329	0.26910	0.28940	0.35830	0.26950	0.28740	0.30110	0.02030	0.08920	0.01790	0.03160
2	330	0.14170	0.13480	0.20520	0.11030	0.09390	0.11540	-0.00690	0.06350	-0.01640	0.00510
3	331	0.14140	0.15280	0.25830	0.09865	0.10320	0.12270	0.01140	0.11690	0.00455	0.02405
3	332	0.31920	0.30230	0.37730	0.36260	0.33290	0.37590	-0.01690	0.05810	-0.02970	0.01330
3	333	0.32100	0.26190	0.32930	0.13860	0.12930	0.14530	-0.05910	0.00830	-0.00930	0.00670
3	334	0.25260	0.24460	0.26500	0.31080	0.28400	0.26540	-0.00800	0.01240	-0.02680	-0.04540
3	335	0.28510	0.24410	0.28730	0.36600	0.28950	0.30120	-0.04100	0.00220	-0.07650	-0.06480
3	337	0.12270	0.13370	0.16690	0.09380	0.09849	0.09784	0.01100	0.04420	0.00469	0.00404
3	338	0.32820	0.26740	No test	0.37470	0.28570	No test	-0.06080	No test	-0.08900	No test
3	339	0.47930	0.47310	0.50630	0.54080	0.52980	0.50720	-0.00620	0.02700	-0.01100	-0.03360
3	340	0.20200	0.18530	0.24340	0.15870	0.13820	0.15680	-0.01670	0.04140	-0.02050	-0.00190
3	341	0.37410	0.33340	0.38920	0.09158	0.07905	0.08532	-0.04070	0.01510	-0.01253	-0.00626
3	342	0.20720	0.21160	0.24790	0.24180	0.23920	0.24690	0.00440	0.04070	-0.00260	0.00510
2	343	0.32930	0.32470	0.34880	0.19250	0.18490	0.17920	-0.00460	0.01950	-0.00760	-0.01330
3	344	0.41370	0.37560	0.36730	0.52830	0.46080	0.40380	-0.03810	-0.04640	-0.06750	-0.12450
3	345	0.19430	0.17140	0.20380	0.23210	0.17840	0.17920	-0.02290	0.00950	-0.05370	-0.05290
3	346	0.39010	0.32920	0.32230	0.36360	0.28280	0.24950	-0.06090	-0.06780	-0.08080	-0.11410
3	347	0.30970	0.28960	0.32200	0.37350	0.33380	0.32670	-0.02010	0.01230	-0.03970	-0.04680
3	348	0.34320	0.35090	0.38230	0.45230	0.45220	0.43950	0.00770	0.03910	-0.00010	-0.01280
3	349	0.18940	0.19790	0.23920	0.14180	0.14390	0.15160	0.00850	0.04980	0.00210	0.00980
2	350	0.17070	0.18060	0.20060	0.11460	0.11760	0.11070	0.00990	0.02990	0.00300	-0.00390
3	351	0.31010	0.30140	0.30090	0.36780	0.34650	0.30180	-0.00870	-0.00920	-0.02130	-0.06600
3	352	0.24220	0.23160	0.25560	0.28080	0.25710	0.24430	-0.01060	0.01340	-0.02370	-0.03650
3	353	0.25540	0.21830	0.24420	0.30950	0.23980	0.22830	-0.03710	-0.01120	-0.06970	-0.08120
3	354	0.23580	0.24800	0.26850	0.29160	0.30610	0.29670	0.01220	0.03270	0.01450	0.00510
2	355	0.32190	0.34590	0.37420	0.05113	0.05552	0.05711	0.02400	0.05230	0.00439	0.00598
3	356	0.21300	0.21700	0.25580	0.12630	0.12530	0.12980	0.00400	0.04280	-0.00100	0.00350
3	357	0.20320	0.17770	0.24110	0.14830	0.12040	0.15940	-0.02550	0.03790	-0.02790	0.01110
3	358	0.14140	0.13070	0.16160	0.11450	0.09829	0.10610	-0.01070	0.02020	-0.01621	-0.00840
3	359	0.23230	0.20060	0.24950	0.28700	0.23360	0.28140	-0.03170	0.01720	-0.05340	-0.00560
2	360	0.42230	0.40440	0.44020	0.54570	0.51390	0.48250	-0.01790	0.01790	-0.03180	-0.06320
2	361	0.16140	0.17400	0.19460	0.12970	0.13850	0.12950	0.01260	0.03320	0.00880	-0.00020
3	362	0.29060	0.28340	0.38700	0.37670	0.35690	0.44610	-0.00720	0.09640	-0.01980	0.06940
3	363	0.27100	0.28620	0.38350	0.29170	0.30680	0.40600	0.01520	0.11250	0.01510	0.11430
2	364	0.05145	0.29550	0.33000	0.00832	0.01472	0.01424	0.24405	0.27855	0.00640	0.00592
2	365	0.29300	0.12800	0.15850	0.01047	0.09814	0.10050	-0.16500	-0.13450	0.08767	0.09003
2	366	0.06745	0.13870	0.17300	0.03209	0.11060	0.11970	0.07125	0.10555	0.07851	0.08761
2	367	0.17440	0.21050	0.23740	0.22090	0.20100	0.20430	0.03610	0.06300	-0.01990	-0.01660
2	368	0.17580	0.17110	0.21230	0.07183	0.18460	0.20500	-0.00470	0.03650	0.11277	0.13317
2	369	0.31470	0.23990	0.35010	0.40650	0.30240	0.41180	-0.07480	0.03540	-0.10410	0.00530

Figure F-12. Vendor 2 Refresh Times Measured at V_{CC}=8.0 volts (Worst-case bits)

2	370	0.29920	0.21930	0.27460	0.37220	0.24660	0.28060	-0.07990	-0.02460	-0.12560	-0.09160
2	371	0.12680	0.30350	0.37160	0.05342	0.31730	0.36290	0.17670	0.24480	0.26388	0.30948
2	372	0.25620	0.29340	0.31370	0.08142	0.27600	0.27300	0.03720	0.05750	0.19458	0.19158
2	373	0.18150	0.28010	0.35240	0.09476	0.26760	0.31000	0.09860	0.17090	0.17284	0.21524
2	374	0.20470	0.20710	0.24850	0.16600	0.16850	0.17980	0.00240	0.04380	0.00250	0.01380
2	375	0.35250	0.34070	0.41430	0.14400	0.13490	0.15660	-0.01180	0.06180	-0.00910	0.01260
3	376	0.17550	0.15920	0.20550	0.14030	0.11870	0.15310	-0.01630	0.03000	-0.02160	0.01280
3	377	0.21120	0.17420	0.25340	0.16460	0.14560	0.17300	-0.03700	0.04220	-0.01900	0.00840
3	378	0.18570	0.15110	0.23450	0.14290	0.12460	0.15880	-0.03460	0.04880	-0.01830	0.01590
3	379	0.18440	0.17050	0.22280	0.14350	0.12560	0.14080	-0.01390	0.03840	-0.01790	-0.00270
2	380	0.21840	0.18200	0.23890	0.15160	0.11780	0.14720	-0.03640	0.02050	-0.03380	-0.00440
2	381	0.51660	0.13050	0.17240	0.27210	0.09285	0.11260	-0.38610	-0.34420	-0.17925	-0.15950
2	382	0.20430	0.16810	0.26090	0.15400	0.11430	0.12310	-0.03620	0.05660	-0.03970	-0.03090
2	383	0.20040	0.16670	0.20840	0.15670	0.11780	0.12720	-0.03370	0.00800	-0.03890	-0.02950
2	384	0.13610	0.11940	0.17820	0.10340	0.08297	0.10030	-0.01670	0.04210	-0.02043	-0.00310
2	385	0.39920	0.32060	0.40840	0.02306	0.03312	0.07359	-0.07860	0.00920	0.01006	0.05053
2	386	0.25170	0.21800	0.26190	0.15350	0.12380	0.13790	-0.03370	0.01020	-0.02970	-0.01560
2	387	0.25290	0.21180	0.28210	0.14720	0.11840	0.14910	-0.04110	0.02920	-0.02880	0.00190
2	388	0.17980	0.16160	0.24290	0.13510	0.11330	0.15060	-0.01820	0.06310	-0.02180	0.01550
2	389	0.17460	0.15710	0.21810	0.13630	0.11350	0.12910	-0.01750	0.04350	-0.02280	-0.00720
2	390	0.11870	0.11630	0.15530	0.08857	0.08462	0.09902	-0.00240	0.03660	-0.00395	0.01045
2	391	0.10910	0.10610	0.14670	0.08062	0.07552	0.09275	-0.00300	0.03760	-0.00510	0.01213
2	392	0.14750	0.12880	0.19060	0.10860	0.08501	0.10170	-0.01870	0.04310	-0.02359	-0.00690
2	393	0.14640	0.13580	0.18630	0.11180	0.09625	0.11500	-0.01060	0.03990	-0.01555	0.00320
2	394	0.14310	0.12840	0.17680	0.10010	0.08462	0.10130	-0.01470	0.03370	-0.01548	0.00120
2	395	0.25620	0.23050	0.31470	0.01278	0.04095	0.01322	-0.02570	0.05850	0.02817	0.00044
2	396	0.41180	0.36970	0.47740	0.01840	0.01826	0.02414	-0.04210	0.06560	-0.00014	0.00574
2	397	0.30580	0.25990	0.34970	0.15730	0.12730	0.15420	-0.04590	0.04390	-0.03000	-0.00310
2	398	0.15840	0.13920	0.19530	0.12880	0.10360	0.13420	-0.01920	0.03690	-0.02520	0.00540
2	399	0.28980	0.24320	0.32220	0.18250	0.14370	0.15360	-0.04660	0.03240	-0.03880	-0.02890
2	400	0.30250	0.26590	0.36030	0.21330	0.17750	0.19910	-0.03660	0.05780	-0.03580	-0.01420
2	401	0.16340	0.15130	0.21110	0.10420	0.09265	0.11610	-0.01210	0.04770	-0.01155	0.01190
2	402	0.23100	0.19150	0.27520	0.15950	0.12250	0.15750	-0.03950	0.04420	-0.03700	-0.00200
2	403	0.16610	0.16050	0.22660	0.11840	0.10870	0.12660	-0.00560	0.06050	-0.00970	0.00820
2	404	0.15780	0.14710	0.19690	0.11170	0.09944	0.11030	-0.01070	0.03910	-0.01226	-0.00140
2	405	0.15350	0.13490	0.19250	0.11670	0.09519	0.11770	-0.01860	0.03900	-0.02151	0.00100
2	407	0.20010	0.19120	0.25940	0.15390	0.13960	0.15120	-0.00890	0.05930	-0.01430	-0.00270
2	408	0.18260	0.15700	0.23960	0.12490	0.10140	0.14200	-0.02560	0.05700	-0.02350	0.01710
2	409	0.14250	0.12600	0.16540	0.11150	0.09126	0.10630	-0.01650	0.02290	-0.02024	-0.00520
2	410	0.48120	0.48250	0.76760	0.03465	0.03479	0.09810	0.00130	0.28640	0.00014	0.06345
2	411	0.26980	0.22990	0.31810	0.18270	0.15230	0.16270	-0.03990	0.04830	-0.03040	-0.02000
2	413	0.23580	0.21600	0.28320	0.13430	0.12020	0.13820	-0.01980	0.04740	-0.01410	0.00390
2	414	0.31730	0.28970	0.36080	0.01999	0.01953	0.04972	-0.02760	0.04350	-0.00046	0.02973
2	415	0.16450	0.14760	0.23490	0.13130	0.10790	0.11560	-0.01690	0.07040	-0.02340	-0.01570

Figure F-12. Vendor 2 Refresh Times Measured at V_{CC}=8.0 volts (Worst-case bits)

2	416	0.44180	0.35850	0.43500	0.06739	0.05305	0.05476	-0.08330	-0.00680	-0.01434	-0.01263
2	417	0.22240	0.19660	0.30330	0.16250	0.13260	0.13270	-0.02580	0.08090	-0.02990	-0.02980
2	418	0.14480	0.12580	0.17960	0.10760	0.08782	0.10330	-0.01900	0.03480	-0.01978	-0.00430
2	419	0.48200	0.42480	0.50790	0.03010	0.02732	0.04452	-0.05720	0.02590	-0.00278	0.01442
2	420	0.20300	0.19500	0.23200	0.13780	0.12590	0.11540	-0.00800	0.02900	-0.01190	-0.02240
2	421	0.15990	0.14600	0.20200	0.12650	0.10780	0.12640	-0.01390	0.04210	-0.01870	-0.00010
2	422	0.17510	0.15530	0.19770	0.11950	0.10040	0.11430	-0.01980	0.02260	-0.01910	-0.00520
2	423	0.25330	0.22240	0.28020	0.08725	0.07376	0.08462	-0.03090	0.02690	-0.01349	-0.00263
2	424	0.23320	0.19960	0.27570	0.17390	0.13790	0.16550	-0.03360	0.04250	-0.03600	-0.00840
2	425	0.17680	0.15000	0.23390	0.13850	0.10520	0.13500	-0.02680	0.05710	-0.03330	-0.00350
2	426	0.22150	0.19570	0.25110	0.09976	0.08347	0.09897	-0.02580	0.02960	-0.01629	-0.00079
2	427	0.13400	0.12770	0.19540	0.10310	0.09237	0.12600	-0.00630	0.06140	-0.01073	0.02290
2	428	0.17510	0.14970	0.20140	0.11390	0.09089	0.11020	-0.02540	-0.08750	-0.02301	-0.13560
2	429	0.15470	0.15540	0.21060	0.12500	0.12080	0.14570	0.00070	-0.08560	-0.00420	-0.14500
2	430	0.49230	0.47310	0.62210	0.03684	0.03400	0.04317	-0.01920	-0.58526	-0.00284	-0.06237
2	431	0.29040	0.24950	0.32410	0.19200	0.15620	0.17940	-0.04090	-0.13210	-0.03580	-0.22030
2	432	0.16940	0.15630	0.20190	0.09366	0.08271	0.10180	-0.01310	-0.10824	-0.01095	-0.11490
2	433	0.17880	0.16550	0.22870	0.14160	0.12360	0.14680	-0.01330	-0.08710	-0.01800	-0.16010
2	434	0.13220	0.12170	0.15870	0.09480	0.08125	0.09360	-0.01050	-0.06390	-0.01355	-0.10410
2	435	0.40530	0.32240	0.44880	0.02214	0.01406	0.02593	-0.08290	-0.42666	-0.00808	-0.10883
2	436	0.18600	0.17420	0.23310	0.10260	0.08540	0.10830	-0.01180	-0.13050	-0.01720	-0.12010
2	437	0.12890	0.11530	0.14840	0.09404	0.07714	0.08667	-0.01360	-0.05436	-0.01690	-0.10027
2	438	0.19020	0.14740	0.21290	0.11500	0.08974	0.10940	-0.04280	-0.09790	-0.02526	-0.15220
2	439	0.25790	0.23080	0.29550	0.17460	0.14940	0.16360	-0.02710	-0.12090	-0.02520	-0.19070
2	440	0.22530	0.20130	0.25710	0.14150	0.12010	0.14090	-0.02400	-0.11560	-0.02140	-0.16490
2	441	0.17100	0.16780	0.25390	0.13460	0.11410	0.15250	-0.00320	-0.11930	-0.02050	-0.15570
2	442	0.33770	0.28710	0.36900	0.01483	0.01229	0.01833	-0.05060	-0.35417	-0.00254	-0.06893

Figure F-12. Vendor 2 Refresh Times Measured at V_{CC}=8.0 volts (Worst-case bits)

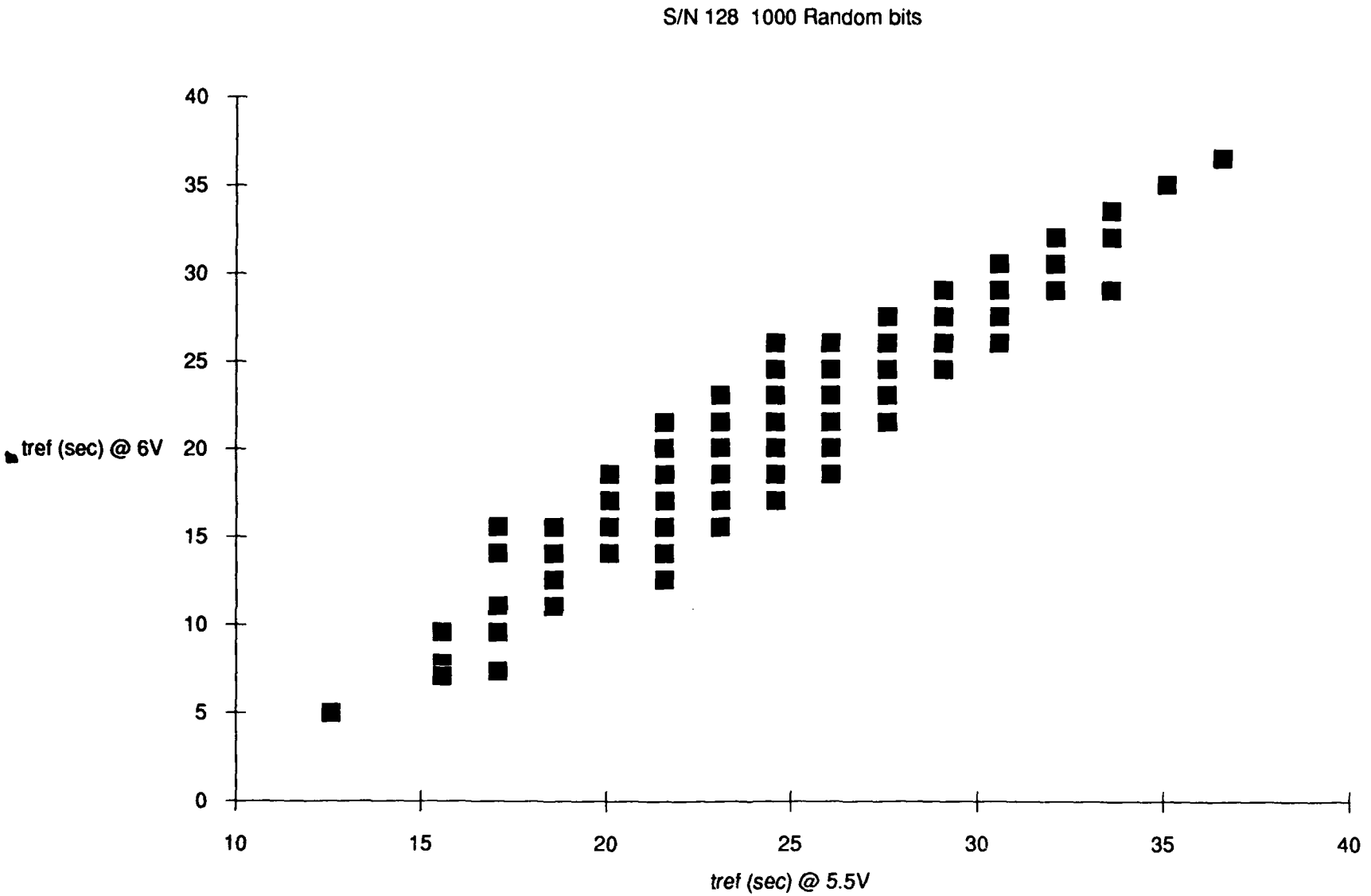

Figure F-13. Scatter Plot of Vendor 1 (S/N 128): 6V vs. 5.5V (Random bits)

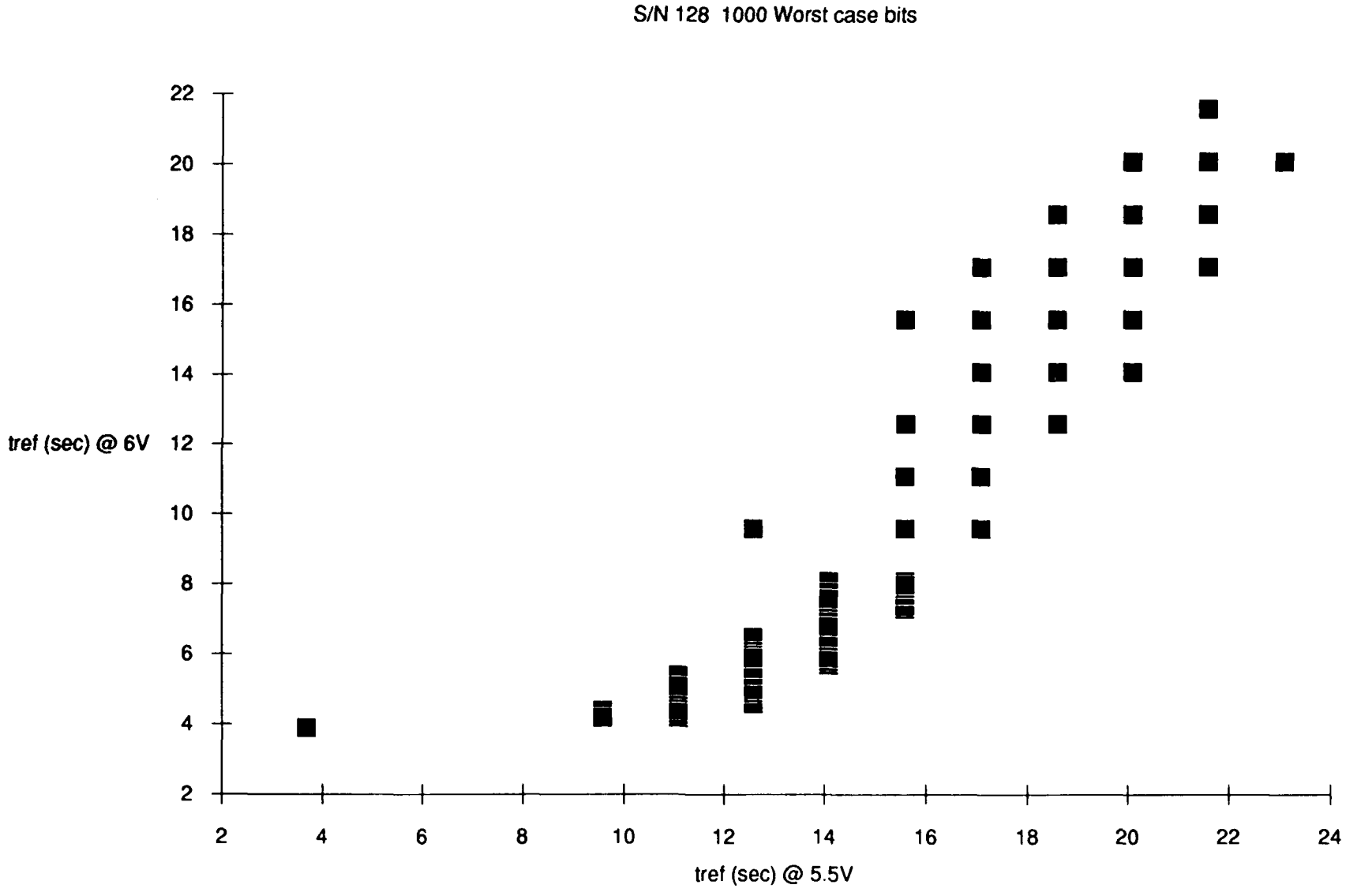

Figure F-14. Scatter Plot of Vendor 1 (S/N 128): 6V vs. 5.5V (Worst-case bits)

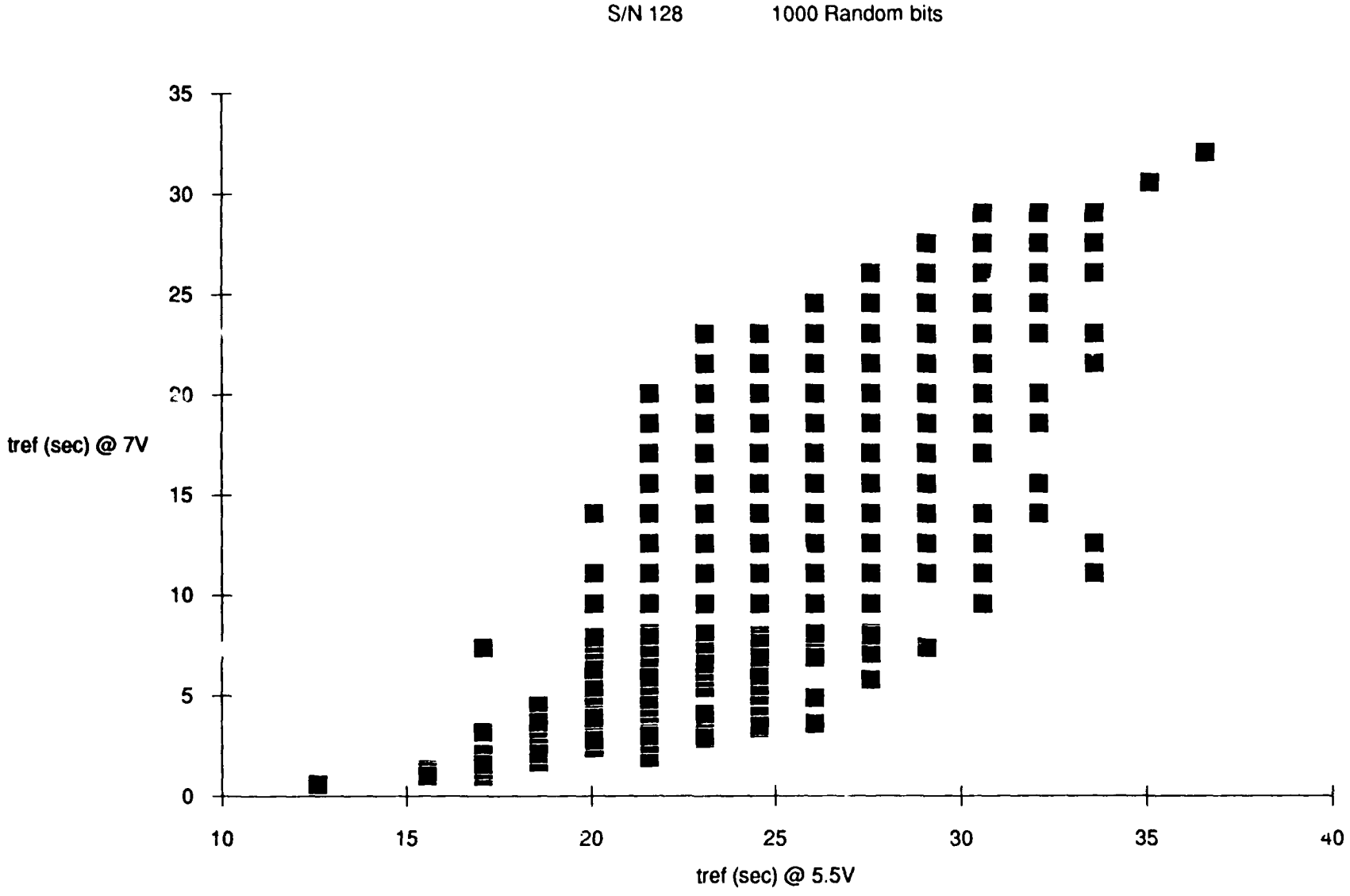

Figure F-15. Scatter Plot of Vendor 1 (S/N 128): 7V vs. 5.5V (Random bits)

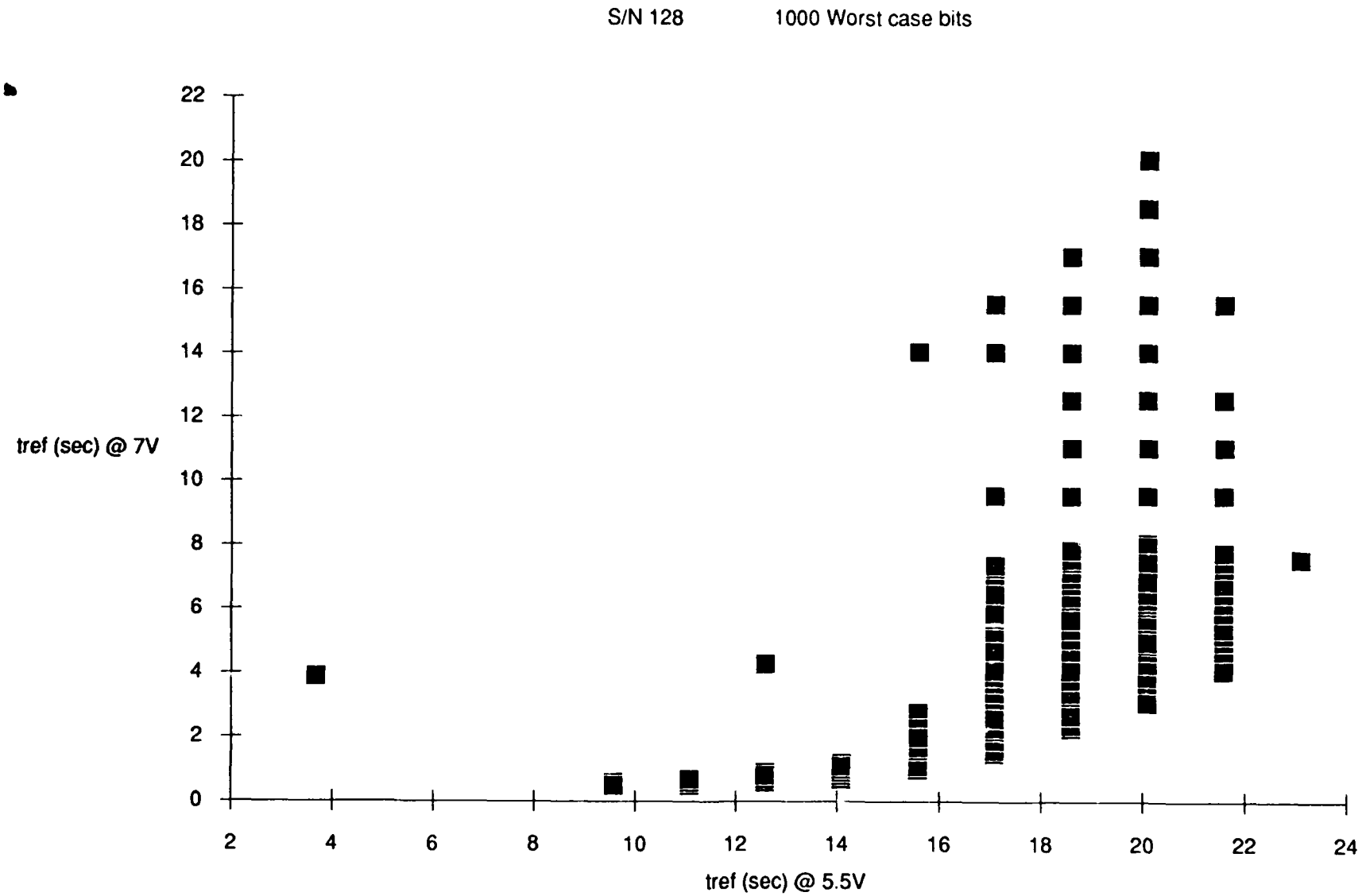

Figure F-16. Scatter Plot of Vendor 1 (S/N 128): 7V vs. 5.5V (Worst-case bits)

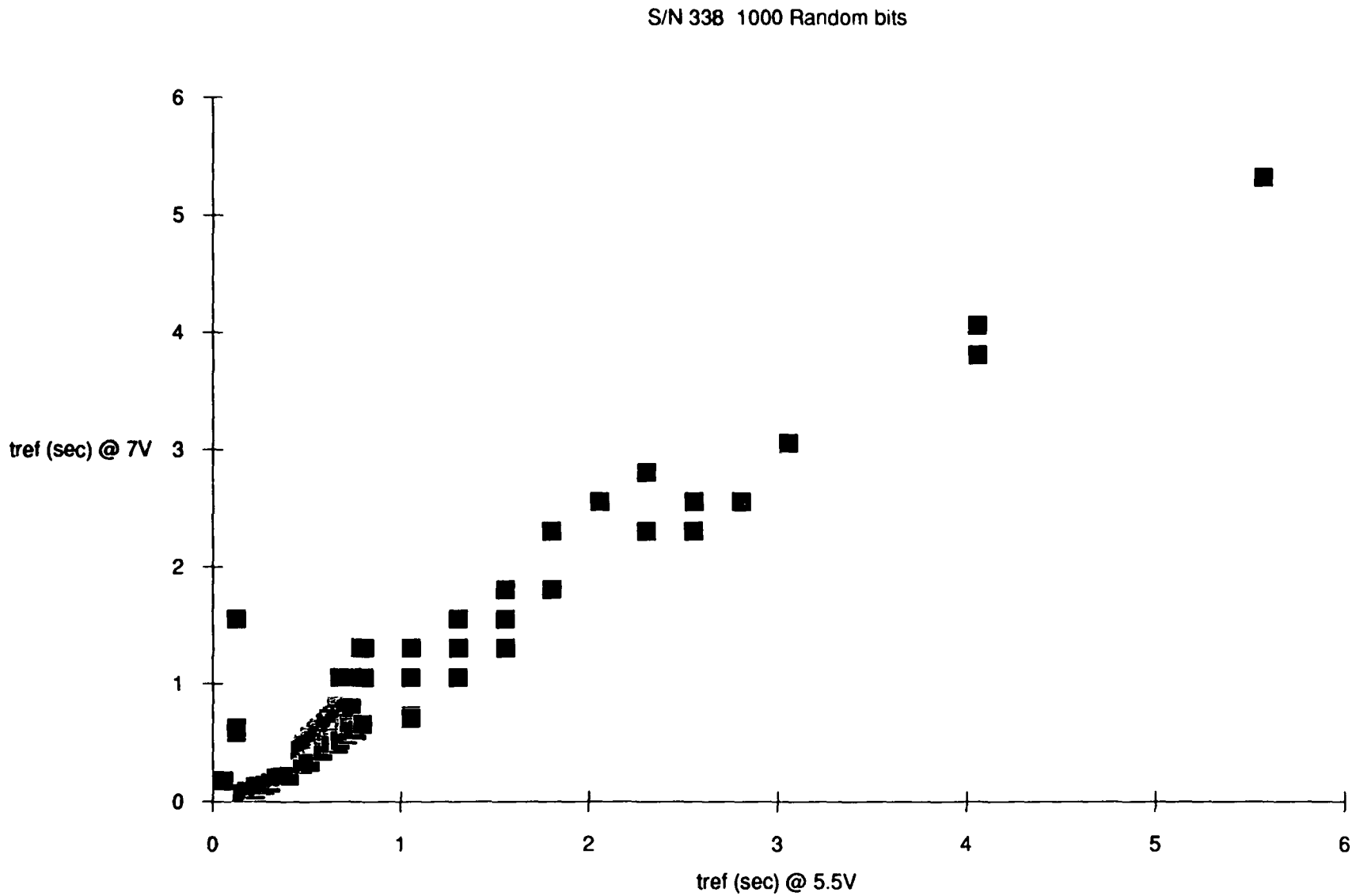

Figure F-17. Scatter Plot of Vendor 2 (S/N 338): 7V vs. 5.5V (Random bits)

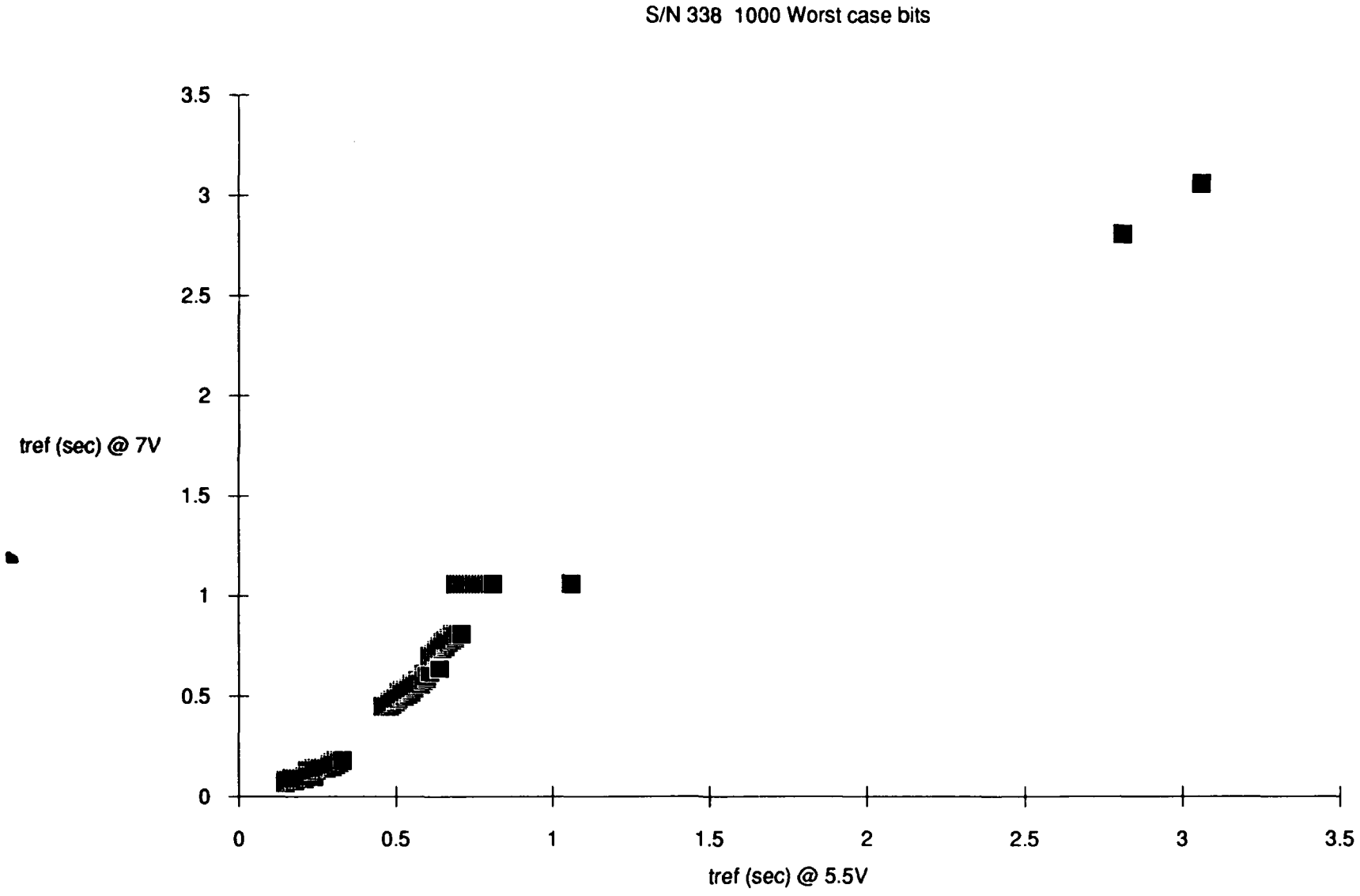

Figure F-18. Scatter Plot of Vendor 2 (S/N 338): 7V vs. 5.5V (Worst-case bits)

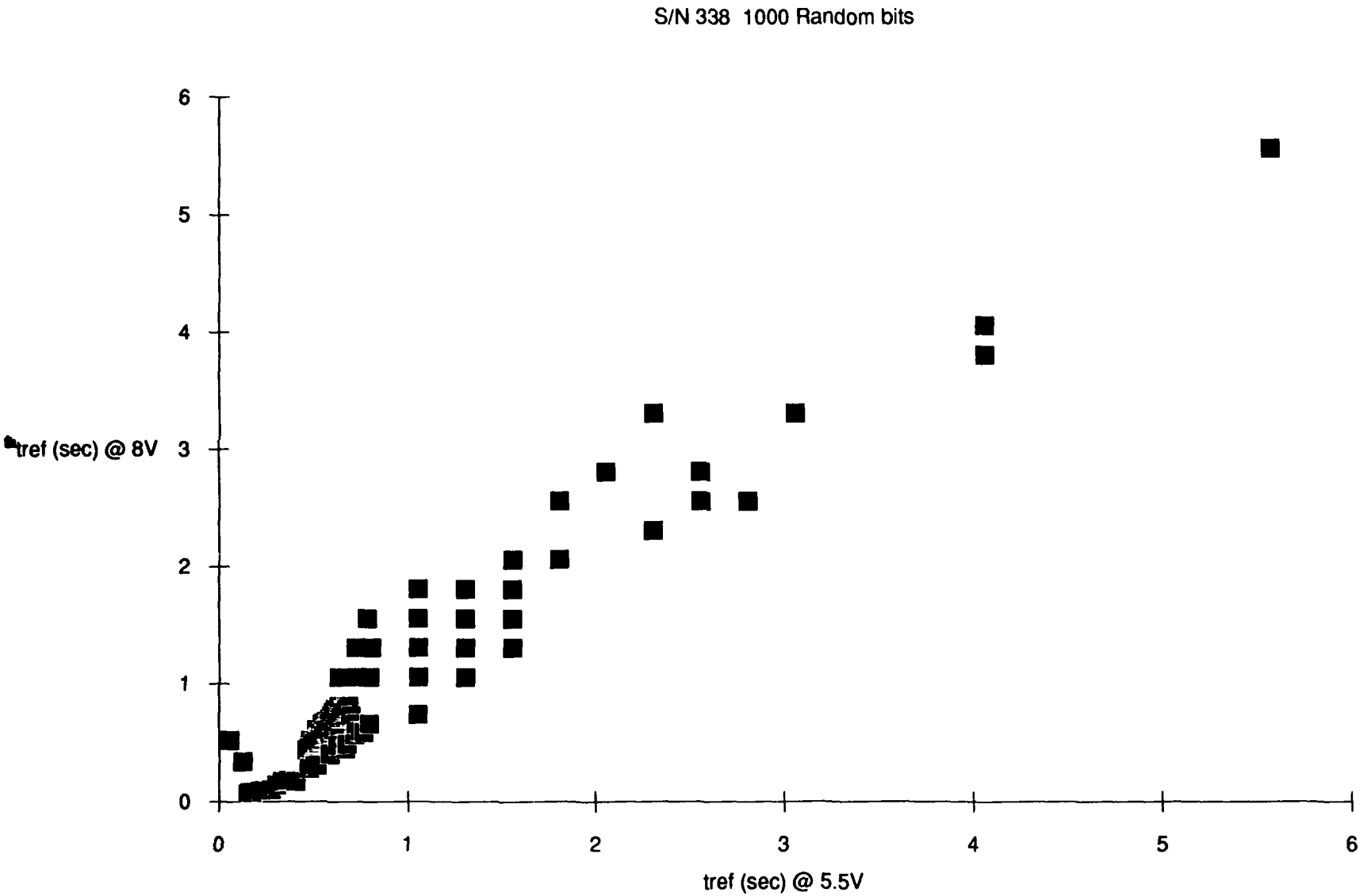

Figure F-19. Scatter Plot of Vendor 2 (S/N 338): 8V vs. 5.5V (Random bits)

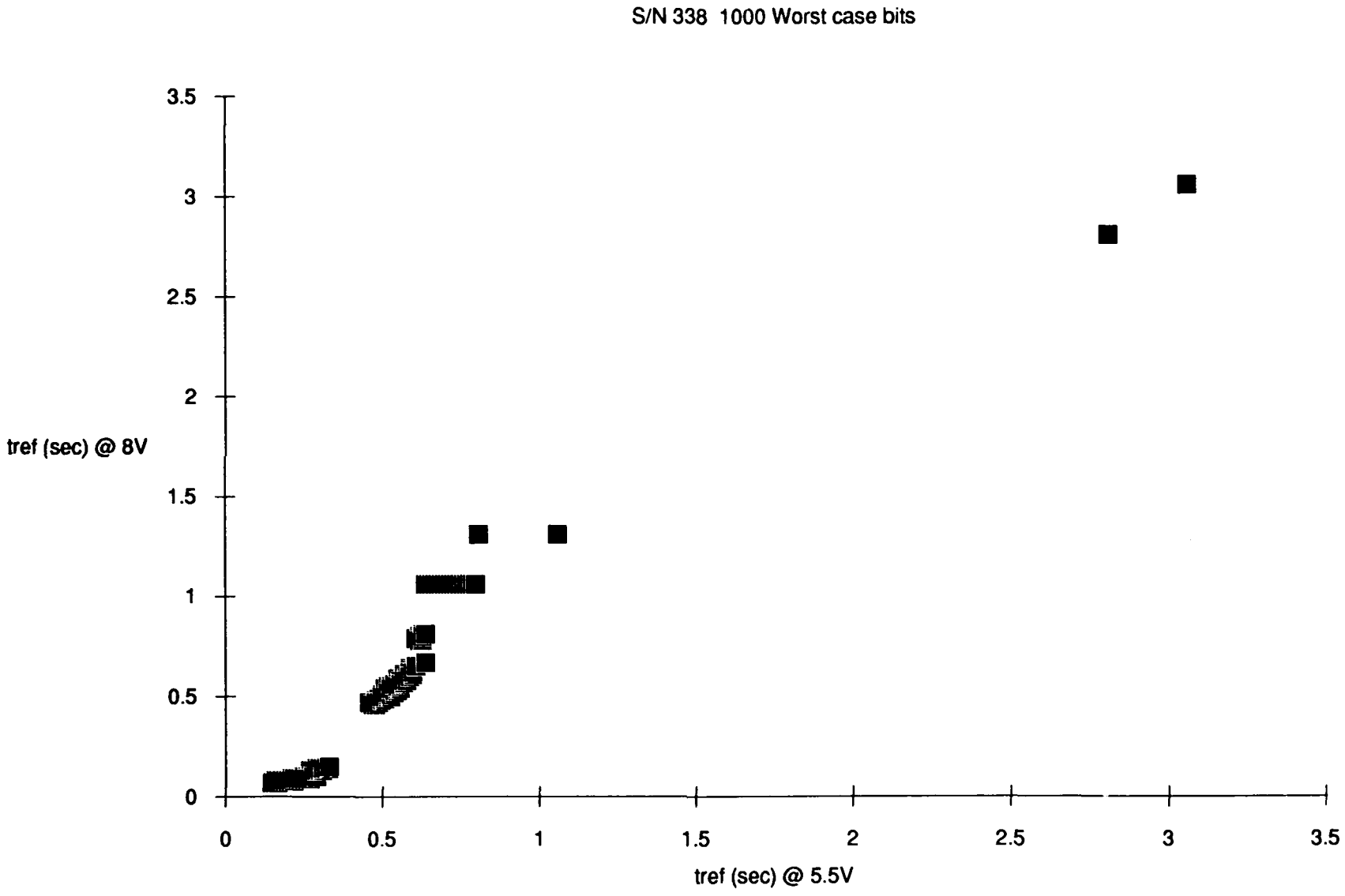

Figure F-20. Scatter Plot of Vendor 2 (S/N 338): 8V vs. 5.5V (Worst-case bits)

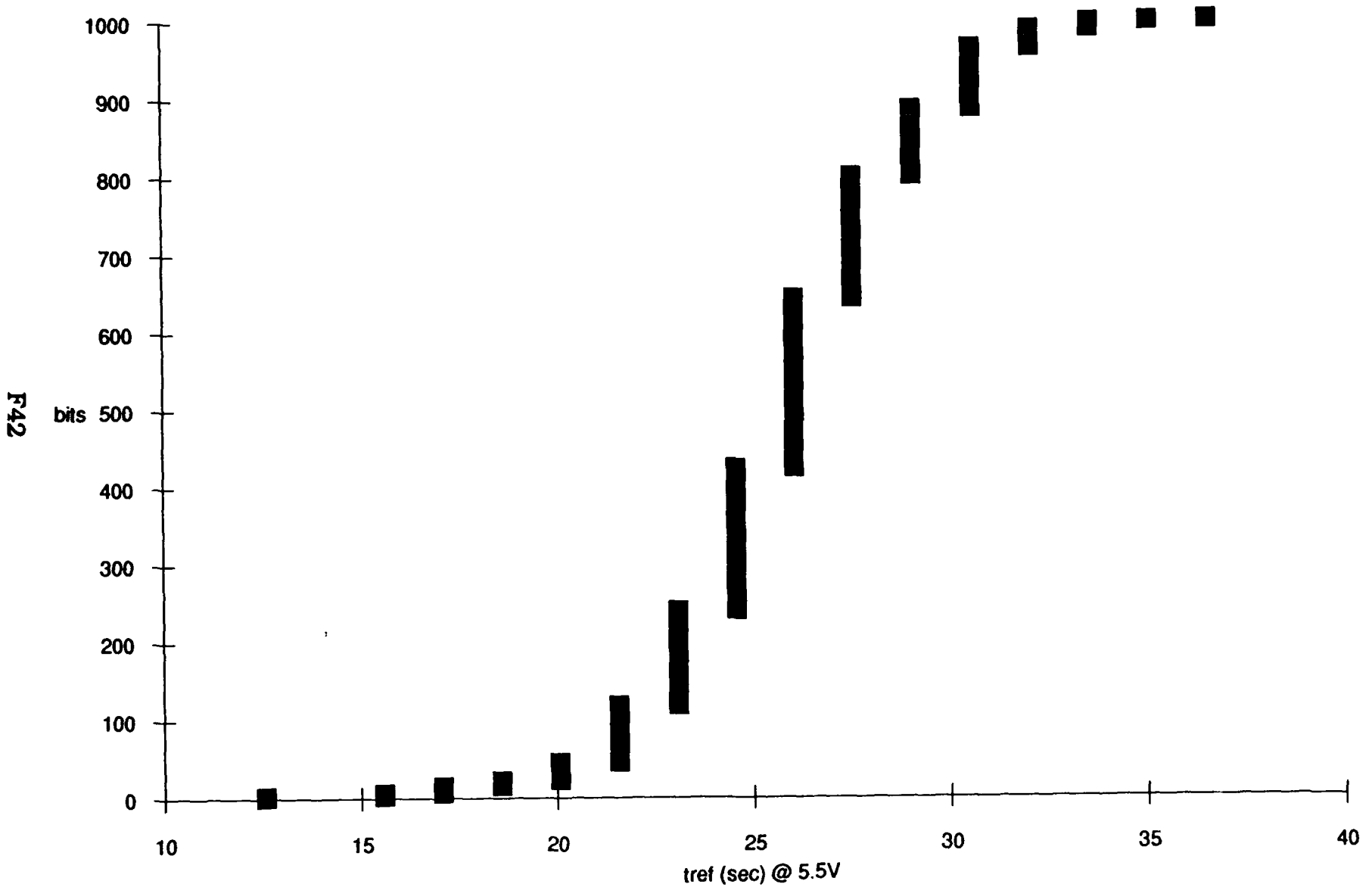

Figure F-21. Vendor 1 (S/N 128) Cumulative Refresh Times: 5.5V (Random bits)

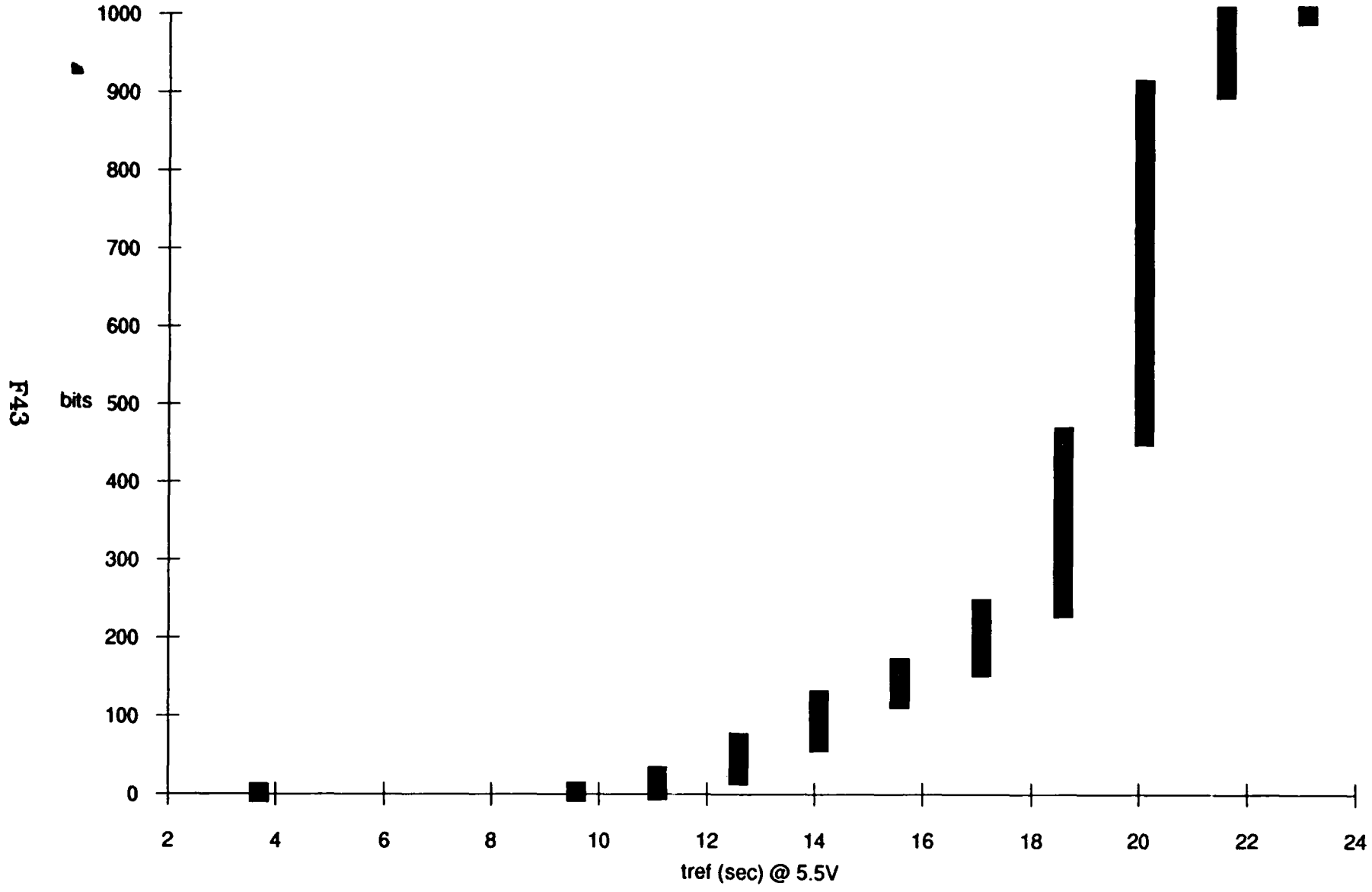

Figure F-22. Vendor 1 (S/N 128) Cumulative Refresh Times: 5.5V (Worst-case bits)

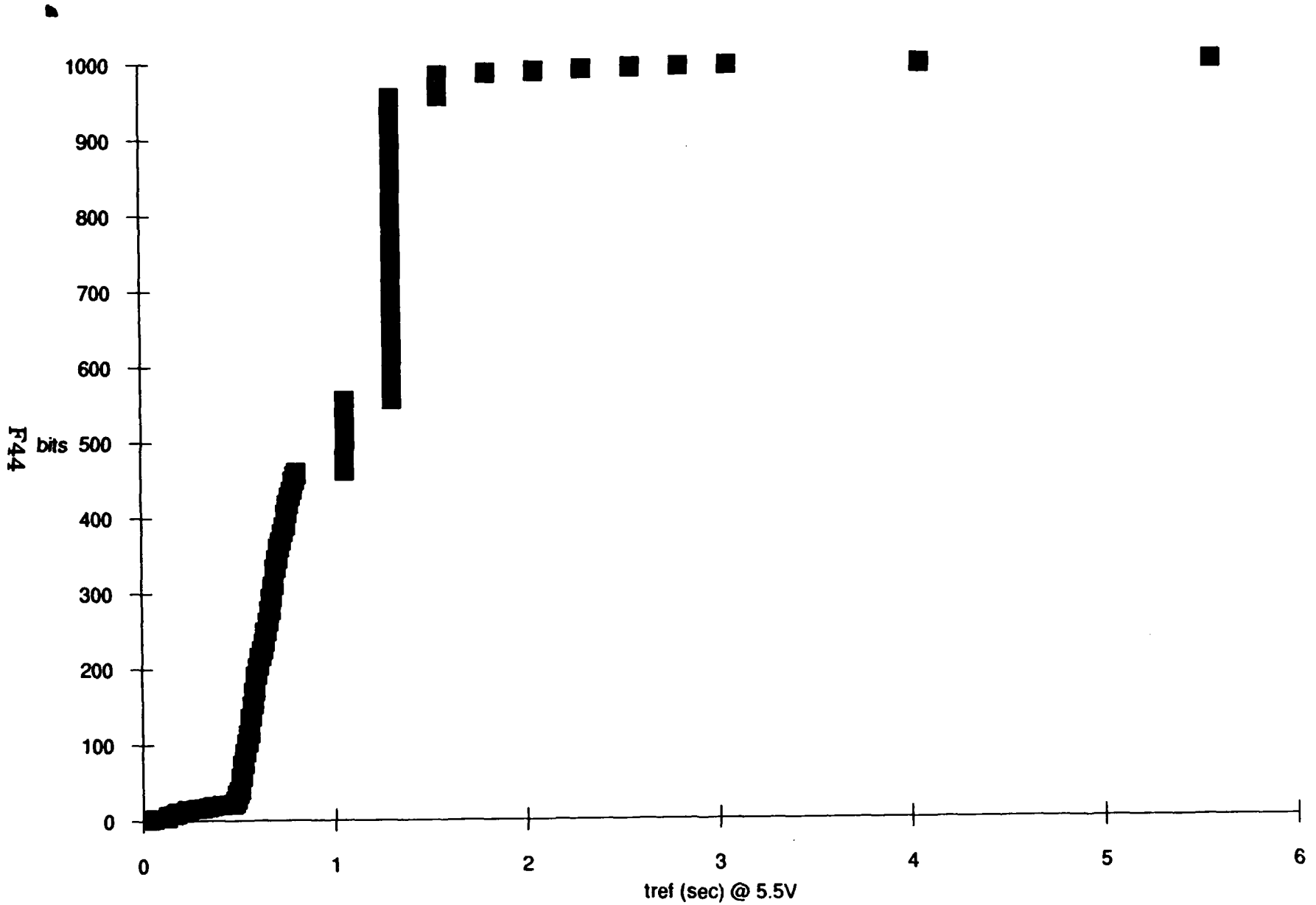

Figure F-23. Vendor 2 (S/N 338) Cumulative Refresh Times: 5.5V (Random bits)

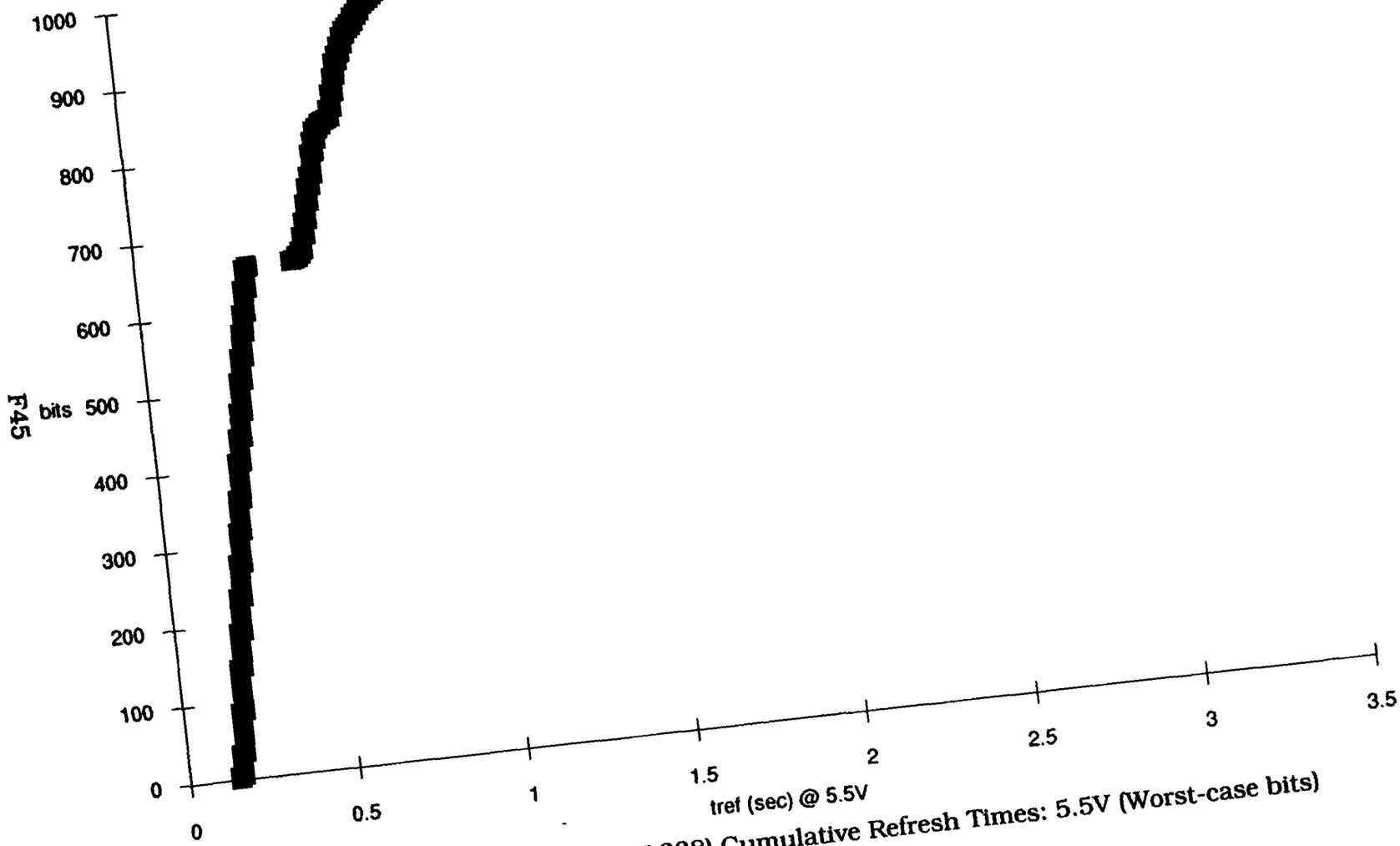

Figure F-24. Vendor 2 (S/N 338) Cumulative Refresh Times: 5.5V (Worst-case bits)

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